Oct. 15, 1940. N. E. DAVIS ET AL 2,218,309

THERMIONIC VALVE APPARATUS FOR USE ON VERY SHORT WAVE LENGTHS

Filed Feb. 27, 1935 3 Sheets-Sheet 1

Fig. 1

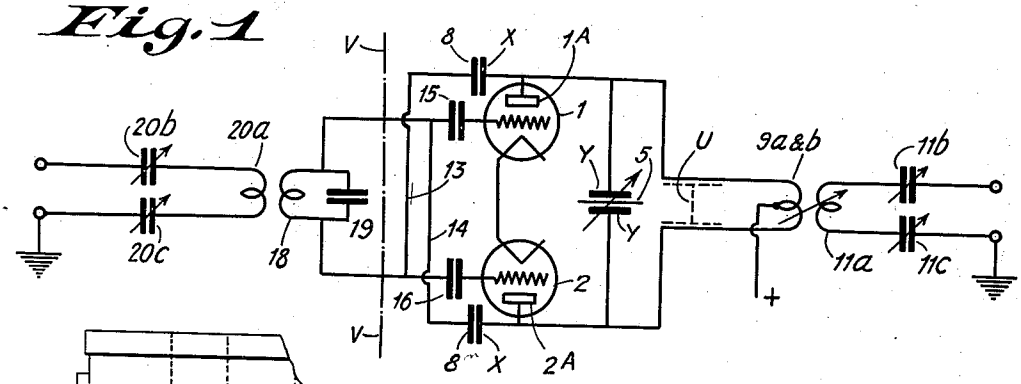

Fig. 2

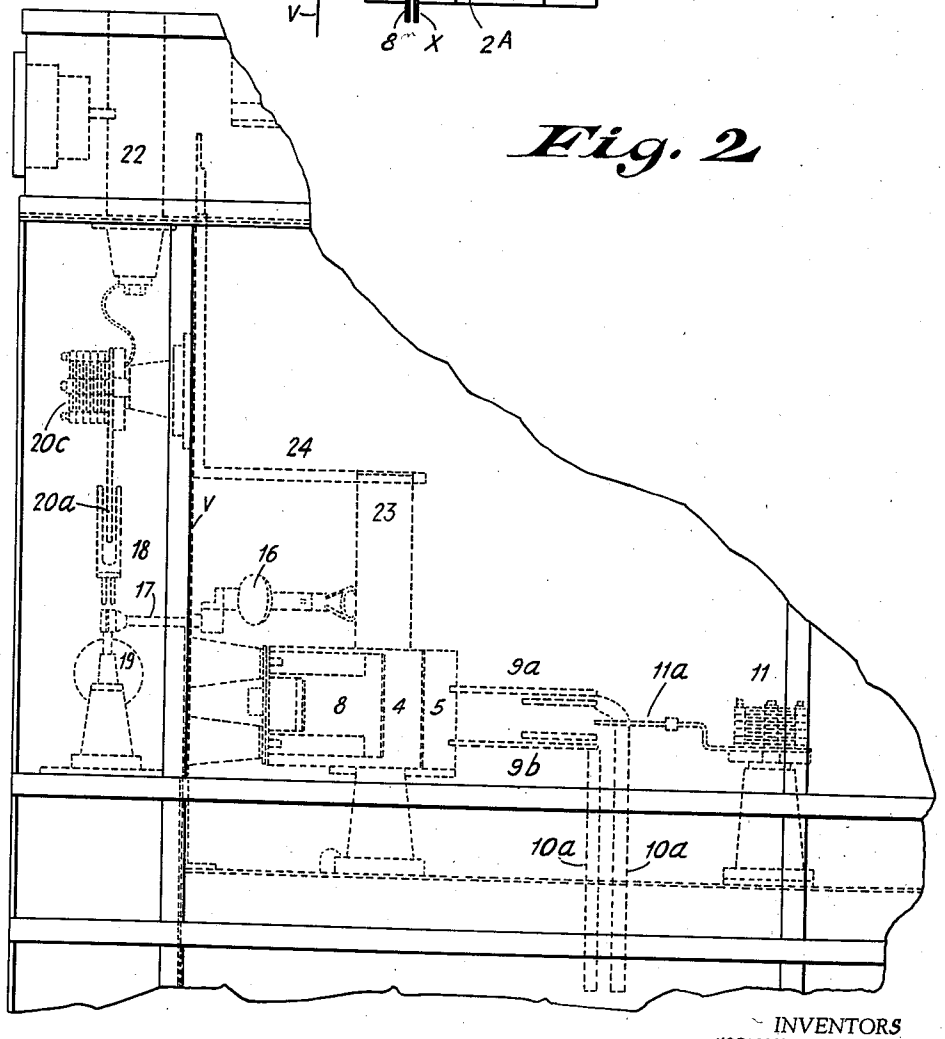

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Fig. 3

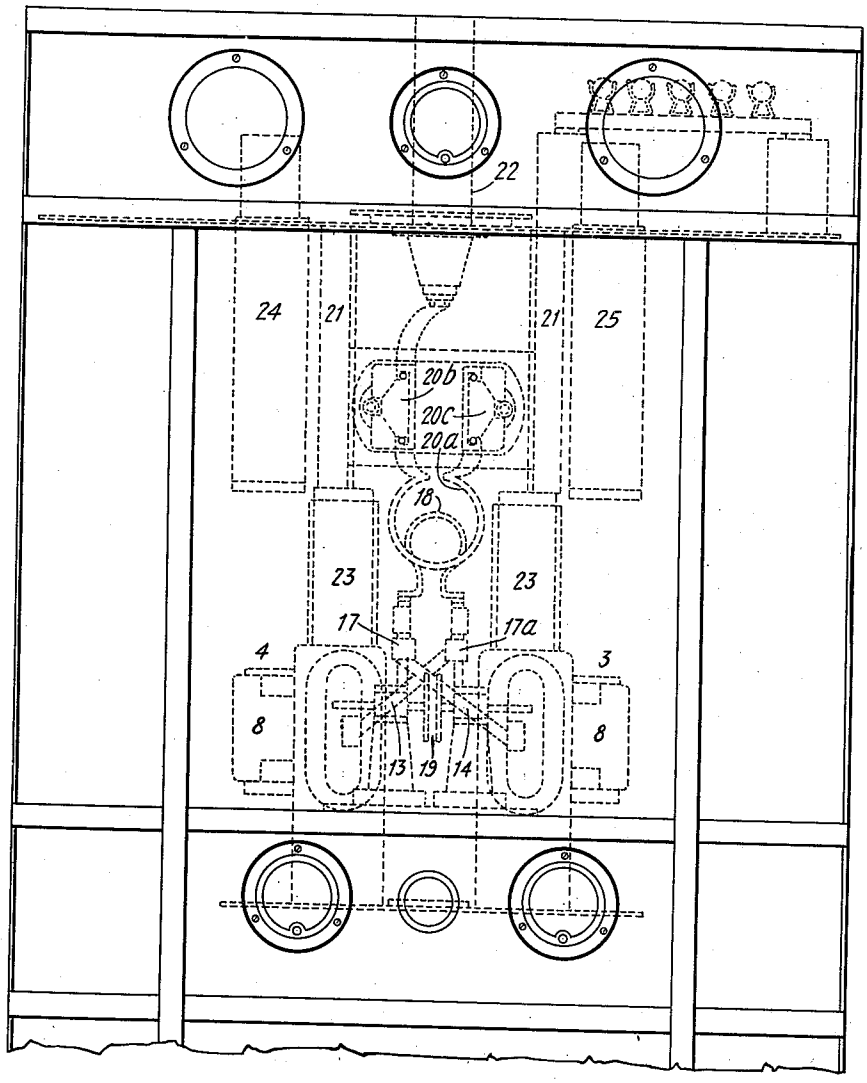
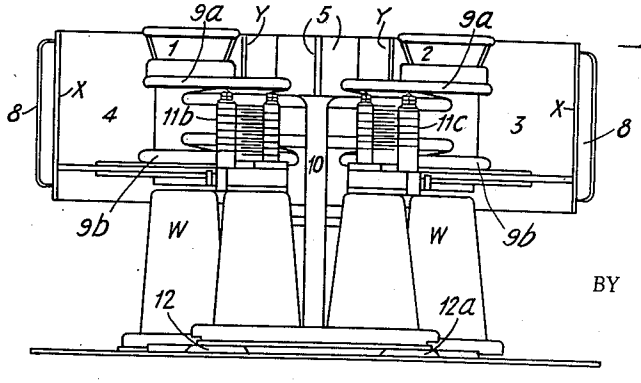


Fig. 6



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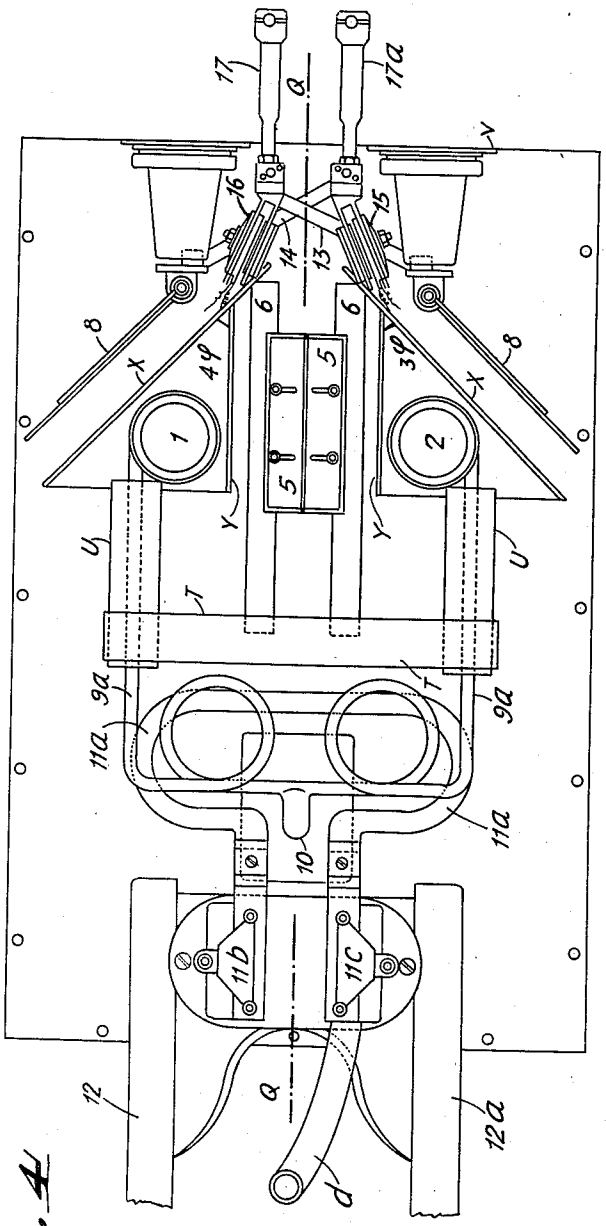

Fig. 4

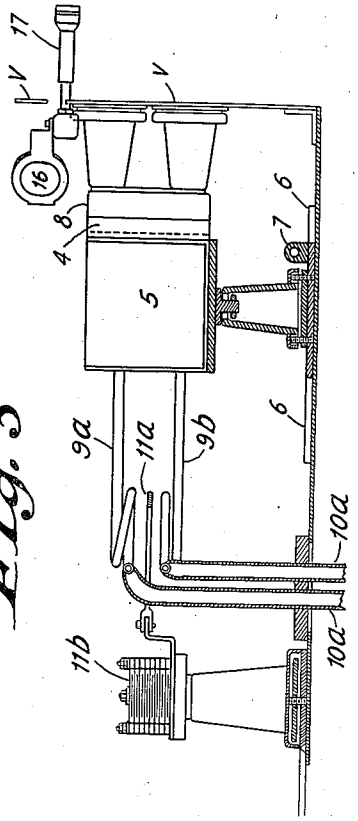

Fig. 5

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THERMIONIC VALVE APPARATUS FOR USE ON VERY SHORT WAVE LENGTHS

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Application February 27, 1935, Serial No. 8,470
In Great Britain March 10, 1934

7 Claims. (Cl. 179—171)

This invention relates to thermionic valve apparatus for use on very short wave lengths and more specifically to thermionic valve arrangements suitable for use in radio circuits adapted to operate upon wave lengths of the order of ten meters or less.

The invention may be utilized to provide an improved very high frequency amplifier and there will later be described in this specification a preferred form of very high frequency amplifier which can be satisfactorily employed on a wave length of about six to eight meters.

As is well known, satisfactory and efficient thermionic amplifiers, for use on very short wave lengths of the order in question and for operation at high power, are difficult to construct. The requirements of such a high power very short wave amplifier may be generalized as follows:

(*a*) The circuit must be electrically symmetrical.

(*b*) There shall be electrical symmetry relative to earth.

(*c*) Stray and uncontrollable capacitative and electromagnetic couplings shall be avoided.

(*d*) Interconnecting leads shall be as short as possible and as few as possible.

(*e*) The whole assembly shall be compact and rigid.

The present invention provides a thermionic valve apparatus in which the above requirements are satisfied to a very high degree, said apparatus being moreover comparatively cheap and easy to construct.

As will be seen more clearly later, the principal features of the invention reside in (1) the arrangement of symmetrically connected thermionic valves in containing screens or housings which also serve as electrodes in anode tuning and neutralizing condensers; (2) the provision of input and output circuits each symmetrically formed and each constructed as an easily removable unit so that it may be adjusted when away from the other apparatus; (3) the provision of variable input and output couplings which may be varied by moving the input and output circuits as units without at all upsetting the symmetry and electrical constants of the whole arrangement; (4) the utilization as part of the output inductance of an arrangement of metal tubes which are also employed to carry cooling water to the valves and the provision in association with said metal tubes of tuning means whereby the output inductance may be varied without interfering with the water connections and with a minimum of alteration to subsidiary apparatus; (5) the utilization as part of the output inductance of the arrangement of tubes which also serve to conduct cooling water to and from the valves, and the construction of said tubes in such manner that they present a desired, relatively high resistance and thereby give the whole amplifier a desired wide, band-pass characteristic. This last feature is one which is only required in cases where the amplifier is intended to amplify a carrier wave modulated with a wide band of frequencies, e. g., a television modulated carrier wave, and in cases where the wide band-pass characteristic is not required, the tubes would be constructed to be of low high-frequency resistance.

The invention is illustrated in the accompanying drawings which relate to a preferred form of high frequency amplifier suitable for use on a wave length of the order of from 6 to 8 meters.

In the drawings:

Fig. 1 is a circuit diagram;

Fig. 2 is a side elevation showing the amplifier general arrangement as seen through the side wall of its container cubicle;

Fig. 3 is a front elevation of the arrangement shown in Fig. 2, the parts being again shown dotted since they are behind the front panel of the cubicle;

Fig. 4 is a plan view of Fig. 2 rotated 180° showing the principal parts of the apparatus on the output side of the screen V;

Fig. 5 is a sectional elevation on a reduced scale through the line Q, Q of Fig. 4, again showing only the principal parts; and

Fig. 6 is an end view of the apparatus shown in Fig. 5. Like references have been used for like parts throughout the figures.

Referring to Fig. 1, the high frequency input, e. g., modulated high frequency, is fed through adjustable condensers 20*b*, 20*c* to a coil 20*a* which is variably coupled to a coil 18 tuned by a shunt condenser 19. Opposite ends of the tuned circuit 18, 19 are connected through condensers 15, 16 as shown, to the grids of two symmetrically arranged valves or electronic tubes 1 and 2 which are of the known single ended type having water cooled anodes 1A and 2A which form parts of the envelopes. The valves are cross neutralized by condensers 3X connected between the anode of each valve and the grid of the other. The anodes are connected together through an inductance 9*a* and *b*, which is shunted by a variable tuning condenser arrangement 5YY and the inductance 9*a* and 9*b* is variably coupled to a coil 11*a* whose ends are connected through adjustable condensers

11b and 11c to the output terminals. A screen V and a tuning device U (shown dotted) may be provided if desired. This general circuit arrangement is, of course, well known per se and is only shown in Fig. 1 in order that the actual arrangement with which the present invention is concerned may be more readily understood.

Referring now to Figs. 2 to 6, each valve is mounted, with its anode 1a or 2a downwards, in a triangular metal chair 3 or 4, each chair having two vertical walls X and Y which are arranged so as to substantially shield the supporting insulators W (see particularly Fig. 6). The walls X of the chairs are inclined towards one another and extend well beyond the walls Y, as shown in Fig. 4. The walls X are in electrostatic relationship with conductive plates 8 (see Fig. 4) which, with the said walls X constitute the cross connected neutralizing condensers 8X of Fig. 1. The chairs as a whole are, of course, in direct electrical contact with the anode jackets of the valves which are, of course, at anode potential. The plates 8 are movable, being hinged upon hinges clearly shown in Fig. 4 and, as will be at once apparent, are conveniently arranged for accurate adjustment and neutralization. The plates 8 are cross connected to the grids of the valve through conductors 13 and 14 respectively; thus the conductor 13 connects one of the plates 8 through a condenser 16 to the grid of the valve at 1 in Fig. 4, while the other plate 8 is connected through conductor 14 and condenser 15 to the grid of the valve at 2. The grid leads from the condensers 15, 16 are shown broken off in Fig. 4, but they continue in a direction to bisect the angles ϕ at the corners of the triangular chairs. The ends of the conductors 13 and 14 remote from the plates 8 are also electrically and mechanically united with conductors 17, 17a which pass through apertures in a screen wall V and are formed at their ends as clamps or sockets for receiving or clamping plugs formed on or carrying the grid tuning coil 18, as is clearly shown in Fig. 3. It will be seen that this construction results in a very rigid assembly with very short cross and interconnecting leads and good shielding of the input circuit. The coil 18 is tuned by a condenser 19 (see Fig. 3), the plates of which are carried upon stems mounted upon the same insulators that help to carry the structures 17, 17a, 13, 14, 15 and 16. Furthermore, as will appear more clearly later, the inductance 18 is at right angles to the inductance in the output circuit. The anodes of the valves are cooled by water led thereto through pipes 9a, 9b which also constitute the anode inductances. These pipes are in parallel and their arrangement will be best seen from Figs. 4, 5 and 6. Water connections are made to these pipes via pipes 10, 10a and anode potential is applied via the points at which pipes 10, 10a join pipes 9a and 9b respectively. The anode inductance is tuned by the condenser constituted by the arrangement shown at 5 in electrostatic co-operation with the plates Y of the triangular chairs. The arrangement at 5 consists of a hollow open ended copper box formed of two halves which may be adjusted with regard to their respective distances from the plates Y (see Fig. 4), the whole box being mounted as shown in Fig. 5, so that it may be slid longitudinally with respect to the chairs. The guide plates along which sliding motion occurs are shown at 6; and 7 is an attachment for a suitable mechanical drive. In effect, the box 5 forms a plate whose distance from the plates Y, Y (measured at right angles to the lengths of the guides 6) may be adjusted once and for all and when adjusted the whole box 5 may be moved more or less into the space between the two walls Y, Y.

The output and input circuits are constructed as units and are, as to their general arrangement, very similar. The output circuit consists of a coil 11a which is positioned between and coupled to coils formed in the pipes 9a, 9b, the ends of the coil 11a being connected each to one terminal of an adjustable condenser 11b or 11c, the remaining terminal of one of the two condensers 11b, 11c being directly earthed to frame and the remaining terminal of the other of these two condensers being connected to a tubular output feeder shown at d (Fig. 4). The whole unit 11a, 11b, 11c may, as will be obvious from Figs. 4 and 5, easily be withdrawn and when withdrawn after detaching pipes 10a, adjusted and balanced accurately. When the unit is in position in the apparatus, the coupling between 11a and the inductances constituted by the circular bends in the pipes 9a and 9b may be varied without at all disturbing the symmetry or electrical contents of the arrangement, by sliding the whole output unit, consisting of the parts 11a, 11b, 11c along guides shown at 12, 12a in Fig. 4. The input circuit which is very similar is again made up of a unit consisting of a coil 20a, condensers 20b and 20c, and, as before, the coupling can be varied by vertically sliding the whole unit 20a, 20b, 20c along guides 21 (see Fig. 3), this adjustment being again one that can be made without disturbing the symmetry or electrical constants.

The input feeder is shown at 22 in Fig. 2. In Figs. 2 and 3, 23 represents the glass portions of the envelopes of the valves whose anode jackets are in the chairs 3 and 4 (the grid lead passing out through one of these glass portions to the condenser 16 is clearly shown in Fig. 2) and 24 and 25 are filament bus bars.

It will be noticed that the extensions of the walls X of the chairs beyond the triangular apices assists in electrically isolating the arms 13 and 14 of the bridge circuit. The walls X—Y substantially shield the insulators W and thus minimize dielectric losses by advantageously distributing the high frequency fields. Further, the main tuning control, which is the device for sliding the copper box 5 and which enables the tuning of the whole circuit when on power, is at earth potential while the condenser arrangement 5YY is extremely rigid and should be of highly constant capacity. Again, the insulator supporting this condenser is in the electrical center of the anode circuit, and therefore there would be no heating or dielectric losses at this point.

If in any particular installation an anode inductance, which is lower than that which can be obtained from an arrangement as so far described and illustrated is required, this may be effected by dispensing with the circular bends in the tubes 9a and 9b. A preferred arrangement, however, which may be used whether such circular bends are present or not, and which has the advantage of permitting easy adjustment of inductance, is that illustrated in Fig. 4 (the corresponding parts are not shown in Fig. 5 for the sake of clarity) and consists of two additional metal tubes U of appropriate diameter, surrounding the tubes 9a and 9b, the said tubes U being connected through a third tubular member T of the same or substantially the same diameter. The structure TUU is slidably arranged longitudinally

and by sliding this structure along the pipes, the anode inductance may be accurately adjusted as required without interfering with the water supply to the valves. It will be appreciated that the provision of the member T, though convenient practically, is by no means essential, for in many cases the required inductance could be obtained by using tubes U of fixed length surrounding the tubes 9*a* and 9*b* and rigidly connected thereto, there being no bridge piece.

Apparatus as illustrated in the accompanying Figs. 2 to 6 may, with slight modification, be very satisfactorily employed for the amplification and transmission of a very high frequency carrier wave, e. g., of six to eight meters, modulated with a very wide band of modulation frequencies, e. g., for television purposes. For example, a very slight modification is required in order that the illustrated apparatus may be satisfactorily employed, not as a final output amplifier, but as an intermediate modulated amplifier having a very wide frequency band pass, as for television signals. The modification consists merely in so arranging matters that the anode inductance presents substantial resistance whereby the inductance/resistance ratio is made of the required value to give the required wide band pass.

A preferred method of obtaining the necssary resistance consists in spraying the copper tubes 9*a*, 9*b* with soft malleable annealed iron or other material having similar electrical properties. If this be done, the high frequency currents, which will pass by reason of skin effect mostly along the outsides of the conductors 9*a*, 9*b*, will suffer considerable loss due to the high permeability of the iron surface, while at the same time the advantages of copper piping for carrying the water are still obtained. In broad principle, this method of obtaining loss to secure a desired inductance/resistance ratio consists in utilizing the water passing down the tubes 9*a*, 9*b* to dissipate the required proportion of energy; that is to say, the high frequency loss is induced by reason of the external soft iron coating, but the heat generated by that loss is quickly and efficiently dissipated by reason of heat conduction through the copper pipe to the water. It is found that it is possible to make the anode circuit loss one third of the total output by the method described, and thus to secure a wide band pass characteristic. The advantages of the method described will be at once apparent when said method is compared with the usual known method of obtaining a desired relatively low inductance/resistance ratio namely, the known method which consists in "loading back" a suitable resistance component from the load. If the load were, as is usually the case, a grid circuit and this known method were employed, then, since a relatively small amount of power is required for full grid excitation, a non-inductive load would have to be built around the grid circuit in order to take the additional load required to "throw-back" to the anode circuit the required resistance and loss. For frequencies of the order in question, the provision of such a load circuit will usually be most undesirable, and in fact the stray capacity of such a load circuit would be likely to prejudice the tuning of the grid circuit at the very high frequencies concerned.

Although, in the specifically described and illustrated embodiment of the invention, triodes are employed, the said invention is not limited to the use of this type of valve, and screen grid valves, for example, could be used with advantage. Very little alteration would be required to adapt the illustrated arrangement to incorporate screen grid valves, and if such valves were used, the principal modification would consist in the provision of means for "blocking" the screen grids direct to earth or frame, i. e., connecting them to earth or frame through direct current blocking condensers. Even if screen grid valves were employed for power amplifier work, it is probable that balancing condenser 8X would still be necessary, or at any rate desirable.

What is claimed is:

1. A vacuum tube amplifier system having a pair of mutually coupled input coils and a pair of mutually coupled output coils, each pair of said input and output coils being arranged at right angles to each other pair, an input circuit comprising one of said input coils having a condenser in series with each side of said input coil and terminals on said input circuit, means for sliding said last mentioned input coil and condensers as a unit into operative relation with the other input coil for said vacuum tube amplifier, an output circuit consisting of one of said output coils having a condenser in series with each side of said output coil and terminals on said output circuit, and means for sliding said last mentioned coil and condensers as a unit into operative engagement with the other output coil for coupling with said vacuum tube amplifier.

2. Apparatus as claimed in the preceding claim, characterized by the fact that said vacuum tube amplifier includes a pair of tubes connected in push-pull fashion.

3. In combination, two pairs of metallic condenser plates mounted and arranged opposite each other, each plate of said pair being located at an acute angle with respect to each other, an electronic tube supported within each pair of said plates whereby the anode of said tube is connected to said plates and acts as part of the anode tuning condenser for said tube, and means cooperating with the other of said angularly arranged plates whereby said other plate serves as part of the neutralizing condenser for the grid of an oppositely arranged tube.

4. In combination, two pairs of triangular metallic condenser plates arranged opposite each other, an electron tube mounted within and having its anode connected to each pair of triangular plates, means including a plurality of adjustable plates interposed between each pair of triangular plates for tuning the anode circuit of said tubes, and means including two other adjustable plates in capacitive relation with each pair of triangular plates for neutralizing the inter-electrode capacity of an oppositely arranged tube.

5. Apparatus as claimed in the preceding claim, characterized by the fact that coils are constructed of hollow tubular material to permit the flow of a cooling fluid therethrough, said coils having their axes at right angles to each other and connected across the plates and grids of said tubes.

6. In combination, two pairs of triangular metallic condenser plates arranged opposite each other, an electron tube mounted within and having its anode connected to each pair of triangular plates, means including a plurality of adjustable plates interposed between each pair of triangular plates for tuning the anode circuit of said tubes, means including two other adjustable plates in capacitive relation with each pair of triangular plates for neutralizing the interelec-

trode capacity of an oppositely arranged tube, a hollow tubular conductor connected across the anodes of said tubes, and a plurality of metallic sleeves mounted about portions of said hollow conductor for varying the inductance thereof.

7. An amplifier system comprising two electron amplifier tubes, a pair of mutually coupled inductance input coils and a pair of mutually coupled output coils, each pair of input and output coils being arranged at right angles to each other pair, an input circuit comprising one of said input coils having a condenser in series with each side of said input coil and terminals on said input circuit, means for sliding said last mentioned input coil and condenser as a unit into operative relation with the other input coil of said electron amplifier tube, two pairs of triangular metallic condenser plates arranged opposite each other, each one of said electron tubes mounted within and having its anode connected to each pair of triangular plates, means including a plurality of adjustable plates interposed between each triangular plate for tuning the anode circuit of said tubes, and means including two other adjustable plates in capacitive relationship with each pair of triangular plates for neutralizing the inter-electrode capacity of an oppositely arranged tube, an output circuit consisting of one of said output coils and having a condenser in series with each side of said output coil and terminals on said output circuit, and means for sliding said last mentioned coils and condensers as a unit into operative engagement with the other output coil for coupling with said amplifier.

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