

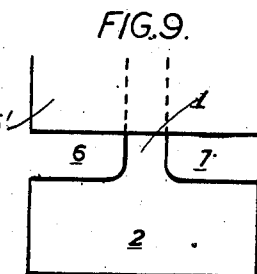
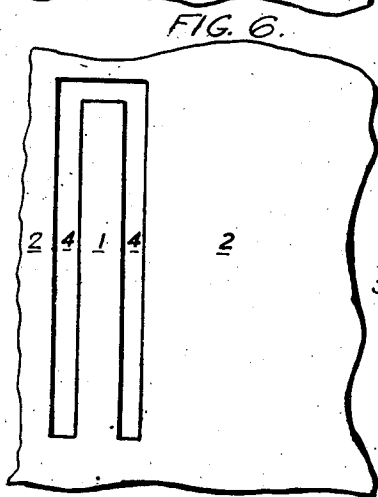
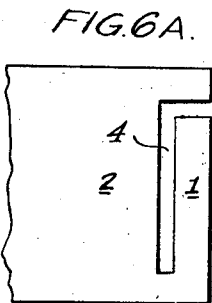
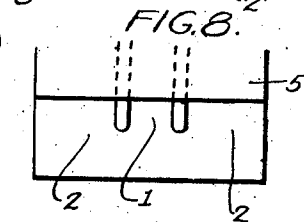
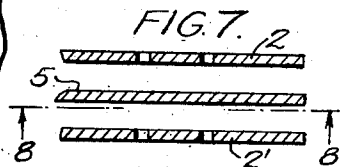
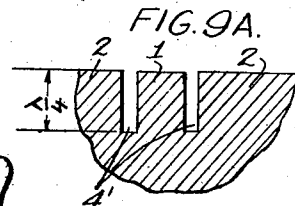
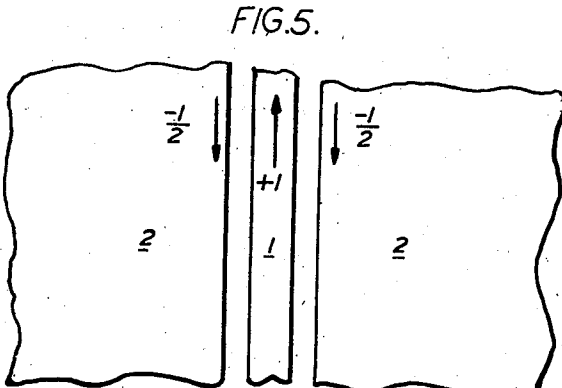
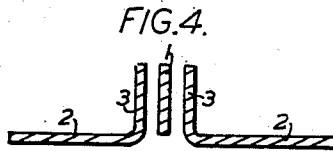
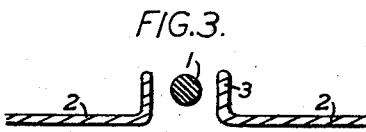
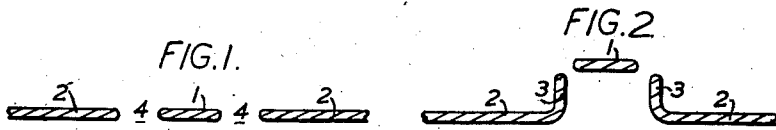
April 26, 1949.

E. O. WILLOUGHBY
COUPLING ARRANGEMENT FOR ULTRA
HIGH FREQUENCY CIRCUITS

2,468,151

Filed April 6, 194

4 Sheets-Sheet 1



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2,468,151

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4 Sheets-Sheet 2

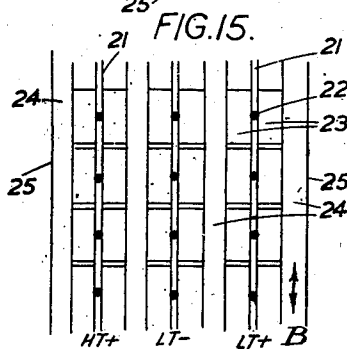
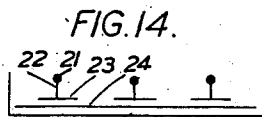
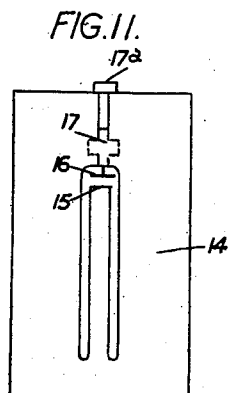
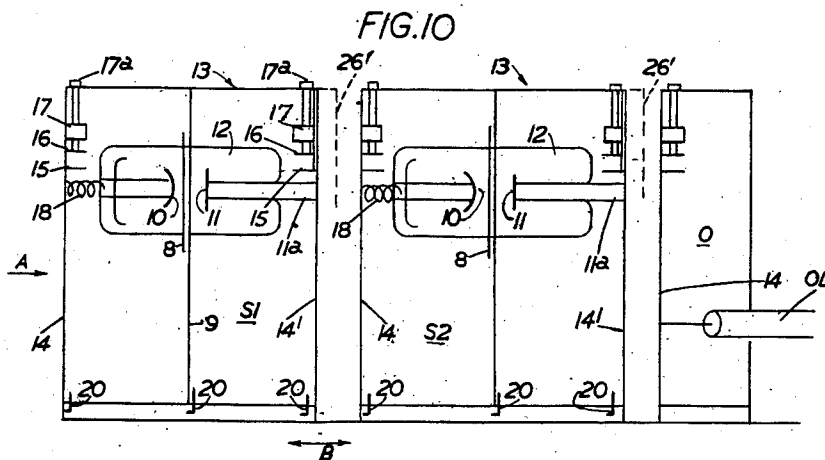


FIG. 17.

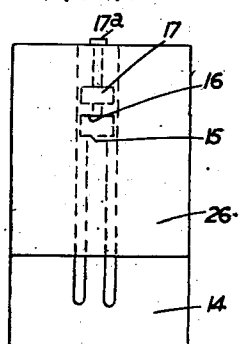
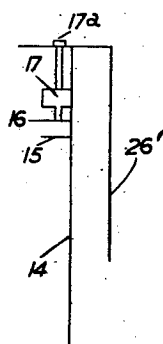


FIG. 16.



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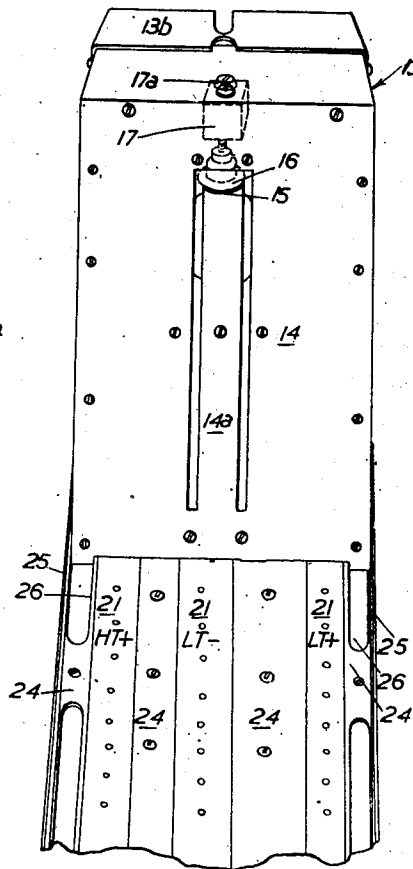
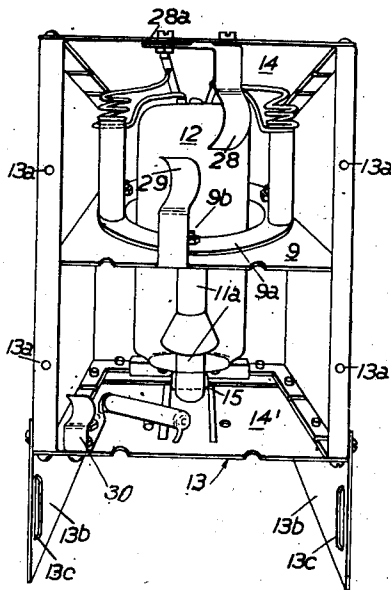
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4 Sheets-Sheet 3

FIG. 13.



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FIG. 19

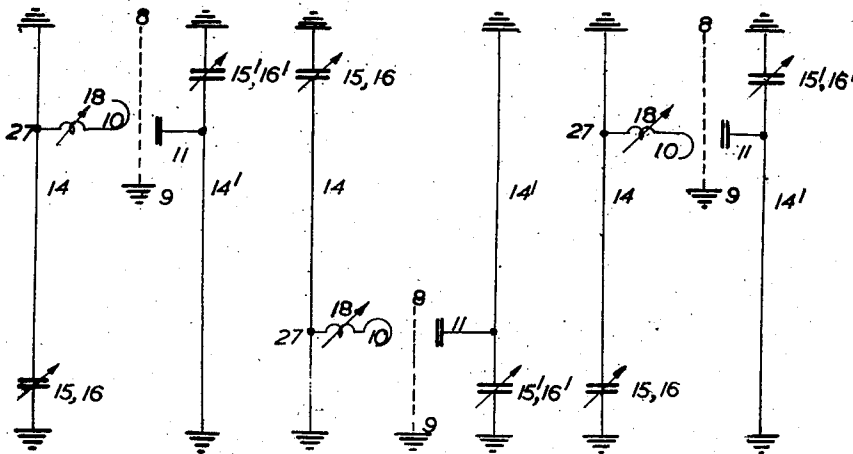
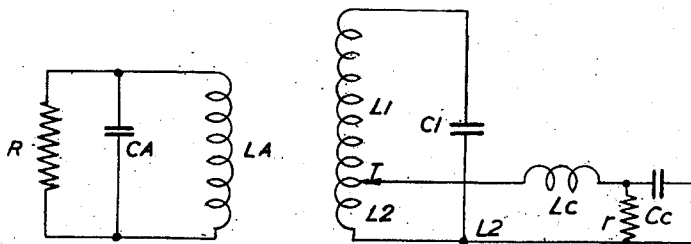


FIG. 18



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UNITED STATES PATENT OFFICE

2,468,151

COUPLING ARRANGEMENT FOR ULTRA
HIGH FREQUENCY CIRCUITS

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Application April 6, 1944. Serial No. 529,715
In Great Britain April 19, 1943

2 Claims. (Cl. 178-44)

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The present invention relates to transmission lines for ultra high frequencies and has for its object to provide transmission lines for use at ultra high frequencies which are of very compact type with low stray field and which may be readily inductively coupled together. A further object of the invention is to incorporate such transmission lines in ultra high frequency apparatus, particularly ultra high frequency amplifiers or other electron discharge apparatus.

According to one aspect of the invention, a transmission line for ultra high frequencies comprises a conducting plate provided with a continuous slot forming a tongue-like portion surrounded on one or both sides by the main portion of said plate. The convenient form for the slot is of U-shape or of L-shape in which latter case one of the limbs terminates in one edge of the plate and the other limb may run parallel with that edge. It will be observed that the tongue is attached to the plate at one end which is thus a short circuited end of the transmission line.

According to another aspect of the invention a transmission line for ultra high frequencies comprises a central conductor and two other conductors arranged one on each side of said central conductor. The conductors may comprise three flat strips in the same plane or arranged with their major faces in parallel planes. Furthermore the two outer conductors may comprise two strips having L-shaped transverse sections with corresponding limbs adjacent and parallel and the major faces of the central strip may be parallel to or perpendicular to the said corresponding limbs.

The characteristics of the lines according to this invention may be varied in a number of ways. For example, by varying the shape or width of the slot, and the thickness of the plate, it is possible to vary the distributed inductance and/or capacity. Furthermore in the case of the triple conductor according to this invention the same factors may be varied and in the case of the L-shaped outer conductors the length of the adjacent limbs or their distance apart from the central conductor as well as the shape of the central conductor may be varied.

According to a modification of the invention, the slots may be replaced by grooves, the depth of which is one quarter of the operating wave length. The groove in this case will then function as an effective open circuited transmission line.

The plate or outer conductors of the triple con-

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ductor transmission line may be earthed, thus providing an unbalanced transmission line of low characteristic impedance and small stray field. Such a line is ideal for inter-coupling ultra high frequency apparatus such as stages in an amplifier. The interstage couplings are simply achieved by close inductive coupling of two transmission lines according to this invention and which form the output of one stage and the input of the next succeeding stage. Such straight ultra high frequency amplifiers are often more convenient than the superheterodyne type of amplifier involving a local oscillator, particularly for the reception of modulated signals of high signal level compared to input circuit noise where it is the rectified high frequency signals which are of interest, or may form an intermediate frequency amplifier for the reception of extremely high frequencies.

The invention will be better understood from the following description taken in conjunction with the accompanying drawings, which show by way of example several forms which the transmission lines embodying the invention may take. In the drawings

Figs. 1-4 are transverse sections of different transmission lines;

Fig. 5 is a plan view of the line shown in Figure 1;

Fig. 6 is a plan view of the triple conductor line short circuited at one end and formed from a conducting plate;

Fig. 6A is a plan view of a modification of the transmission line shown in Fig. 6;

Figs. 7 and 8 are sectional and plan views respectively of an arrangement by which the coupling between two lines can be varied, Fig. 8 being a view looking from the line 8-8 of Figure 7;

Fig. 9 is a plan view of a similar variable coupling arrangement applied to a line made by an isolated tongue attached to a conducting plate;

Fig. 9A is a sectional elevation of a further modification of a transmission line according to the invention;

Fig. 10 is an elevational view of an ultra high frequency amplifier embodying the transmission lines with inductive coupling as interstage coupling arrangements;

Fig. 11 is an end view looking in the direction of the arrow A of Fig. 10;

Fig. 12 is a perspective view of a single unit stage looking from the bottom of Fig. 10;

Fig. 13 is a perspective view of a single unit stage looking in the direction of the arrow A in Fig. 10;

Fig. 10;

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Figs. 14 and 15 show elevational and plan views respectively of arrangements for connecting the high and low voltage supplies to the amplifier stages;

Figs. 16 and 17 show two views at right angles corresponding to the views in Figures 10 and 11 respectively of arrangements for varying the coupling between the stages and similar to the arrangements shown in Figures 7 and 8;

Figs. 18 and 19 are explanatory diagrams.

Referring to the drawings, Figs. 1 and 5 show a central conductor 1 and outer conductors 2, all of which are flat conductors which lie in the same plane. In many instances, in ultra high frequency equipments it is required that the transmission line is short-circuited at one end so as to produce, for instance, a resonant circuit. In such cases, the short-circuited line is easily produced as a tongue by means of a slot 4 as shown in Fig. 6. This slot is here shown as of U-shape but it may of course be of any other shape, such as part of a circle or other curved form, providing it does not form a closed curve. The plate 2 may be removed on one side of the tongue 1, leaving an L-shaped slot 4 terminating in the edge of the plate 2. A transmission line modified in this manner is shown in Fig. 6A. Such lines, however, are not of so much practical importance as the triple conductor type shown in Figure 6 of the drawings, which is cheap to make, and by using narrow slots could be arranged to have a very small field at a distance from the plate.

The triple conductor lines shown in Figures 1-4 have characteristic impedances which decrease from the type of line shown in Figure 1 in succession to the type of line shown in Figure 4. The line shown in Figure 2 comprises a central flat strip conductor 1 and two conductors 2 of L-shaped cross section having the limbs 3 facing and parallel to each other. The major surfaces of the conductor 1 are substantially at right angles to the limbs 3. In the line shown in Figure 3, the central conductor is of rod-like form, and whilst shown as of circular cross-section, may have any other shape of cross-section. In Figure 4 the central conductor 1 is shown as a strip conductor whose major faces are parallel to the adjacent limbs 3 of the outer conductors 2. It will be understood by those skilled in the art that the characteristic impedance of the triple conductor line may be varied in many ways. For example, by varying the distance between the conductors, by varying the length of the limbs 3 in Figures 2-4 or by varying the shape of the central conductor in the case of Figures 2-4, and also in fact in the case of Figure 1.

By increasing the length of the limbs 3 in Figures 2, 3 and 4 the relative magnetic field available for coupling on the lower side of the plates 2 rapidly decreases with only small decrease of characteristic impedance. In any of these cases the full current flows in the central conductor and half the current in each of the outer conductors or plate 2 which may be earthed.

Figures 7, 8 and 9 show an arrangement by which the coupling between two transmission lines according to the invention can be varied. Figure 7 is an elevation in section, Figure 8 is a plan view. Figure 9 is a plan view of a modified line. The transmission line is shown in Figures 7 and 8 as of the same type as that shown in Figure 1 or 6, but it will be understood that the arrangement may be used with any of the lines. Two of the lines are placed parallel to each other so that they are inductively coupled, and a mag-

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netic screen 5 that is, at the frequency in use, any conducting plate, is inserted between the two coupled lines, the length of the screen inserted being variable. The two lines are shown in Fig. 7 as parallel plates 2 and 2', respectively. In this way variable lengths of the transmission lines are coupled. Figure 9 shows a type of transmission line comprising an isolated conductor 1 formed as a tongue by cutting away the portions 6 and 7 of the conducting plate. The other conductor of the line is the conducting plate 5'. This type of line has a large stray magnetic field between the edge of plate 5 and the edge of conductor 2 and is useful where large inductive coupling is required. As in Figures 7 and 8, the coupling between two lines may be varied by means of the adjustable plate 5' which acts as a variable screen when two similar lines are inductively coupled. The stray field may be obtained by means of any transverse conductor, connected to 1, and the edge of the plate 5.

Whilst the conductors have been described as being separated by slots, the conductors may be formed between grooves in a conducting plate, provided the depth of the grooves is substantially one quarter of the operative wavelength, with which the line is to be used. Thus the groove functions as a quarter-wave line short circuited at one end and thus functions as an open-circuited line and no current at the frequencies used will flow in a direction towards the bottom of the groove.

Fig. 9A is a section through a transmission line in accordance with the modification just described. In this embodiment of the invention, the slot 4 of the preceding figures is replaced by a groove 4' which separates the conductor 1 from the remaining portions of the conducting body 2, the depth of the groove being one quarter of a wavelength. Due to this dimensioning of the groove 4', the latter will act substantially in the same manner as the slot 4 in Fig. 1 as will be readily understood by those skilled in the art.

The most practical and useful type of transmission line according to the invention is perhaps the type shown in Figures 1 and 6 formed by slots in a conducting plate, especially when the transmission lines in two different circuits are to be inductively coupled together as a means of coupling the two circuits.

Figures 10 and 11 show in plan and end view a two-stage amplifier for ultra high frequencies in which the stages are coupled together by means of transmission lines according to the present invention; specifically of the type shown in Figure 6.

In the amplifier shown in Figures 10 and 11 each stage (shown in Figures 12 and 13) comprises a thermionic valve of the grid disc or disc seal type. In such valves the grid is connected to a metallic disc 8 which passes through the envelope 12 of the valve and surrounds the grid, and forms a convenient way of making connection to the grid. Such valves are described and claimed for instance in the U. S. Patent Number 2,419,544 issued on April 29, 1947, to J. Foster.

The cathode of the valve is indicated at 10 and the anode at 11. The valve is supported in a screening metal box 13, divided into two compartments by a metal partition 9 provided with means for supporting the valve by the grid disc. These means comprise a ring 9a (Figure 12) between which and the screen 9, the grid disc 8 is clamped with the aid of nuts and bolts 9b. The partition 9 screens the input grid-cathode cir-

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cuit from the output grid-anode circuit. The ends of the box 13 consist of plates comprising transmission lines as shown in Figure 11 which is a view looking in the direction of the arrow A in Figure 10. The plate 14 is of the kind shown in Figure 6.

The open circuit end of the central conductor 14a of each transmission line is bent over to form a plate 15 (Figure 13) of a tuning condenser of which the adjustable plate 16 is carried on a block 17 either supported on the plate 14 itself when at earth potential or carried on a supporting earth plate which is insulated from the plate 14 by a thin layer of sheet mica in cases where the plate 14 is at one of the D. C. supply potentials. The plate 16 is adjustable by means of a screw 17a which screws into the block 17.

The valves are connected to the transmission lines 14 as shown in Figure 10 and for simplicity only the high frequency circuits are shown, it generally being necessary to load the cathode circuit by a loading coil 18 to form an equivalent three-quarter wave-length loaded transmission line on the cathode side of the circuit, and the anode lead 11a may be directly connected on to the central conductor of its transmission line 14' to form an equivalent quarter-wave loaded transmission line. Because of the short operating wave-length the loaded transmission line on the cathode side of the circuit is made three-quarter wave-length in order that a voltage antinode can be obtained outside the valve envelope. If this loaded line were only one-quarter wave-length the antinode would fall within the valve envelope.

The transmission lines constituting the input and the output circuits of each amplifier stage are coupled together as illustrated in the case of the amplifier units S1 and S2, and in the case of the amplifier stage S2 and the output unit O. The current antinodes at the short circuit points 19 (Figure 11) of the transmission lines 14, 14' are arranged to be at the same height, and relatively close spacing between the coupled circuits, for example, 14' of S1 and 14 of S2, or 14' of S2 and 14 of O, is found necessary even at critical coupling, but over-coupling to produce a frequency band pass characteristic is possible. It will be observed that the amplifier stages are made in units. These units are adjustably located on rails, as shown in Figures 13, 14 and 15, and secured thereon by means described hereinafter.

These rails are indicated at 21 in Figures 14 and 15 and are associated with H. F. filters decoupling the D. C. supply lines 21 for H. F. currents to earth. These filters are composed of the inductive component of 21 produced by spaced connections 22 to condenser plates 23, and the condensers formed by plates 23, a dielectric sheet 24 and the earth tray 25 carrying the units and supporting the rails 21. The rails in Figure 13 are shown somewhat differently, but forming condensers with the tray 25. In Figure 13 the rails 21 are shown as broader strips than in Figure 15, and are in direct contact with a continuous plate 24 of insulating material. The condensers are thus formed between the rails 21 and the tray 25.

A cover strip 13b shown in Figure 12 is used between the units S1, S2 and O for screening from external circuits and is attached to the units to form a rigid composite whole together with the fastenings of the units to the tray. The units are

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screwed to the base by slotted holes 26 in the marginal strips of the base plate 25 (Figure 13) so that the distance and hence the coupling between the units can be adjusted in the direction of the arrows B (Figures 10 and 15), and for this purpose the cover plates 13b are provided with slotted holes 13c which enable them to move relatively to the tray 25, bolts being passed through the sides of the tray and the holes 13c to secure the units in position.

Other arrangements utilising transmission lines according to the invention are possible, but the unit construction is greatly aided by the use of such transmission lines for the H. F. circuits both in compactness and ease of screening due to the small stray field associated with such lines and the excellent decoupling inherent in the transmission line plates of the amplifier units.

Connection between the H. T. and L. T. rails and their respective electrodes is made by means of springs 28, 29 and 30 (Figure 12), one making contact with each rail when the box 13 is placed home on the tray 25. The springs are appropriately connected to the electrodes and the anode is capacitively coupled to the transmission line 14' for H. F. currents but is insulated therefrom for direct current. Similarly the cathode is capacitively coupled to line 14 for high frequency currents but is insulated therefrom for direct currents. These capacities may be formed at any convenient point in the circuits. For example, the spring 28 is supported by but insulated from line 14 by means of a mica strip as shown at 28a. This forms the L. T.+ terminal for the cathode heater, or the cathode terminal if the heater forms the cathode, and is insulated from the earthed box 13. The other cathode heater spring contact 29 is connected directly to the partition 9 which is at earth potential (D. C.). The box 13 may be held firmly in position by means of spring clips 20 as shown in Figure 10 as an alternative to the bolts and nuts which pass through the slotted holes 26 in the marginal portion of tray 25 and through the holes 13a shown in Figure 12 of the box 13.

Circuit elements associated with each amplifying stage are located within the box 13 in a convenient manner.

For applications where very small coupling is required between the units or stages a screen plate 26' shown in Figures 16 and 17 is inserted between the units, or on the other hand there may be one such screen plate 26 on each unit, coupling being adjusted by adjusting the uncovered portions of the coupled transmission lines.

The output transmission line is shown as a coaxial line OL and the central conductor of this is connected in the vicinity of a voltage nodal point on the input transmission line 14 of the unit O which is coupled to the last amplifying stage.

In wide band amplifiers at ultra high frequencies, the inductively coupled types of band pass units are simplest, but unless the "Q's" of the two coupled circuits are approximately the same, full power output will not be obtained at the peaks of the band pass frequency versus voltage curve, and full power at the peaks makes a flat band pass possible with a single peak tuned correcting stage, without appreciable drop of gain.

One difficulty to be surmounted in the inverted valves of the type commonly used for ultra high frequency amplifiers and as described in relation to Figure 10, therefore, is the high ratio

of output to input resistance, coupled with shunt input and output valve capacities of the same order. This is overcome by the methods illustrated in Figure 18 and 19. In Figure 19 parts corresponding to like parts in Figure 10 are given the same references as in that figure. Referring to Figure 18, R is the equivalent output resistance load across the anode of one valve and C_A and L_A the equivalent shunt capacity and inductance of the output circuit, r is the input resistance and C_c the input capacity of the next valve of the amplifier system. So long as the reactance C_c is then about $r/3$, it is possible to series tune the parallel circuit rC_c with an inductance L_c and then by an appropriate tap T on the inductance of a parallel tuned tank circuit L_1C_1 this latter circuit may be so damped as to be of substantially the same Q as the high Q circuit C_AL_A in the anode output circuit of a preceding amplifier stage to which L_1C_1 is coupled.

In practice this is carried out as indicated in Figure 19 where 14 and 14' designate the transmission lines of the amplifier in Figures 10 and 18 a series tuning device corresponding to 18 Figure 10 which is a series capacitance or inductance according to whether the length of the connection from the cathode to the point 27 is greater or less than that required to tune the circuit to one-quarter wave resonance. As pointed out hereinbefore, the electrical length is preferably a quarter wavelength, but if the frequency is high, it may of necessity become three-quarters the operating wave-length.

If the slotted plate comprising the line 14 Figure 19 is used to move as a piston then it is possible by appropriate choice of a fixed reactance at 18 to arrange for a small movement of this plate to series tune the cathode line 10—27 to quarter-wave resonance.

The tapping point 27 is so adjusted that the damping on the input tank circuit is just sufficient to make its effective "Q" the same as that of the output circuit 14' of the preceding amplifier stage to which 14 is coupled.

From the foregoing description it will be observed that the input and output circuits of the amplifier stages are resonant transmission line circuits tuned to the operating frequency. Whilst only one embodiment of the invention has been described by way of example, others falling within the scope of the appended claims will occur to those skilled in the art. Furthermore, many modifications and adaptations may be made in the example described without departing from the scope of the appended claims.

For example, any of the lines described in relation to Figures 1-4 may be used in place of the type shown in Figure 6 as used in the description

of the amplifier given, and these lines may be short-circuited at one end by a conductor in known manner.

What is claimed is;

1. A circuit for ultra high frequencies comprising a plurality of unbalanced energy translating stages and means for coupling successive stages, said means including two inductively coupled transmission lines, each of said lines including a metal plate having a surface forming a main conducting portion and a single tongue-like portion formed in said surface by a slot, said tongue being surrounded by said main portion on at least two of its three sides, said plates being mounted parallel and closely adjacent to one another with said tongues adjacent one another and a shield connected to said surface of each metal plate about said slot and arranged to shield said translating stages.
2. A circuit for ultra high frequencies comprising a plurality of unbalanced amplifying stages including a vacuum tube having cathode, grid, and anode electrodes and a grid disc, and means for coupling successive stages, said means including two inductively coupled transmission lines, each of said lines including a metal plate having a surface forming a main conducting portion and a single tongue-like portion formed in said surface by a slot, said tongue being surrounded by said main portion, said plates being mounted parallel and closely adjacent to one another with said tongues adjacent one another, and a shield connected to said surface of each metal plate about said slot and to the grid disc of the translating stage connected to the corresponding tongue.

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