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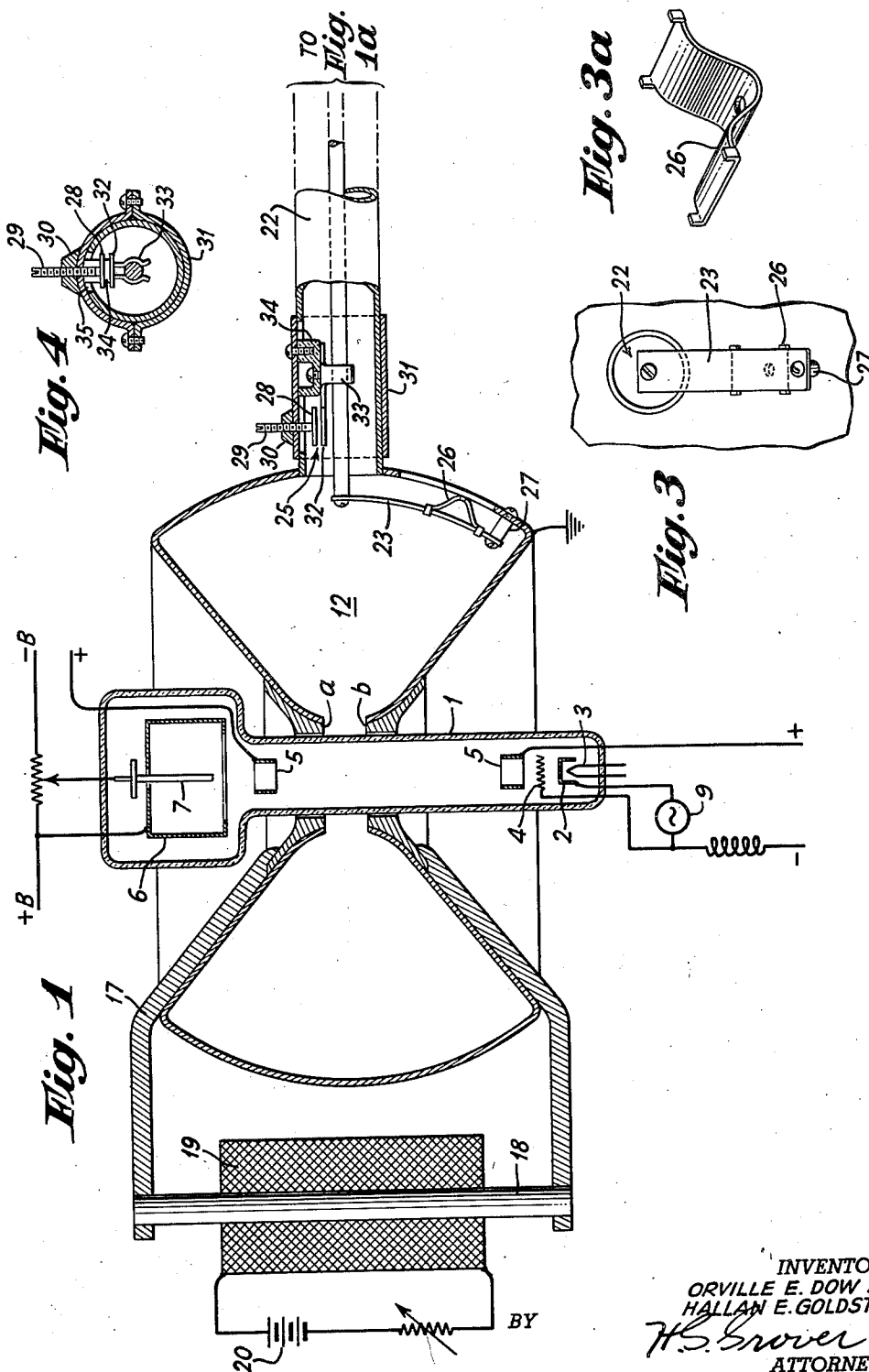
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HIGH FREQUENCY COUPLING CIRCUIT

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HIGH-FREQUENCY COUPLING CIRCUIT

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This invention relates broadly to coupling circuits, and specifically to a band pass coupling circuit for use between the output of an electron discharge device stage and a useful load.

An object of the present invention is to provide a band pass coupling circuit for use between a cavity resonator and a useful load, in which adjustments in tuning can be easily and accurately made.

Numerous features of the present invention reside in the novel mechanical constructions employed in the coupling circuit, whereby both coarse and fine tuning is achieved by parts which are compact, easily assembled, and provide inherent shielding for the energy traversing the coupling circuit.

The following is a description of the invention accompanied by drawings, wherein:

Figs. 1 and 1a, taken together, illustrate the coupling circuit of the invention applied between the output circuit of an electron discharge device stage and a useful load;

Fig. 2 shows an electrical circuit equivalent to the coupling circuit of Fig. 1 and given for the purpose of more clearly explaining the principles of the invention;

Fig. 3 is a detail showing another view of the coupling loop employed for deriving energy from the cavity resonator for subsequent passage to the useful load;

Fig. 3a is a detail of the slide employed on the coupling loop for adjusting the degree of coupling;

Fig. 4 is a cross-sectional view of the variable condenser construction which serves as a micrometer adjustment; and

Fig. 5 is a cross-sectional view of the junction point of the coupling circuit between the main coaxial line and the adjustable tuning inductance.

Referring to Fig. 1 in more detail, there is shown an electron discharge device stage comprising a vacuum tube structure consisting of an evacuated glass envelope 1 containing within it a cathode 2, a heater 3, a grid 4, ringlike accelerator electrodes 5, collector electrode 6 and a suppressor 7. The heater is supplied with energy from a suitable source of current (not shown). Connected to the cathode 2 and grid 4 is a suitable source of radio frequency energy 9 which may comprise a master oscillator or the output of a preamplifier stage. The collector electrode 6 for gathering the electrons traversing the length of the glass envelope 1 is cup-shaped in form. Centrally located within the interior of the collector 6 is provided the rod-like sup-

pressor electrode 7 for gathering secondary electrons which may emanate from 6. Surrounding the exterior of the glass envelope 1 and located intermediate the two accelerator electrodes 5, 5 there is provided a high Q, low loss tank circuit 12 in the form of a surface of revolution whose central plane is perpendicular to the electron beam emanating from the cathode 2. This circuit, it should be noted, is in the form of an hour-glass and is symmetrically arranged around the glass envelope 1. The dimension of the tank circuit 12 as measured from the center of the glass envelope 1 toward the arc of any one sector is usually approximately one-quarter of the length of the communication wave corresponding to the resonant frequency. The tank circuit which is preferably made of a high electrically conducting material, such as copper, has a gap a, b adjacent the glass envelope, and is excited by electrons traversing this gap through the interior of the glass envelope 1. In effect, the tank circuit 12 may be considered to be an electrical resonator of the cavity type.

For focussing the electron beam there is provided a magnetic lens which is serially arranged with respect to an iron magnetic path. This magnetic path includes a strip of iron 17 which is placed adjacent to the sides of one of the sectors of tank 12, as shown in the drawings, and which is completed through an iron core 18, in turn surrounded by an electromagnetic field coil or solenoid 19 excited by a direct current source of supply 20. If desired, this magnetic path may be replaced by a permanent magnet arrangement to achieve the same result.

The electron discharge device circuit just described forms no part of the present invention per se, and is more completely described in a United States application, Serial No. 296,045, filed September 22, 1939, by Mr. Fred H. Kroger, now United States Patent 2,350,907, granted June 6, 1944, to which reference is herein made for a more complete description of the operation of a device of this type. In general, this kind of electron discharge device is called an inductive output tube, because the tank circuit is adapted to be excited by the inductive action of the electron beam rather than by direct impingement of the electrons.

The coupling circuit of the present invention for abstracting energy from the tank circuit 12 and for delivering the same to a suitable utilization circuit which may be an antenna or other useful load (herein shown connected to a transmission line 21) comprises a coaxial line 22, one

end of which is connected to the transmission line 21 and the other end of which is coupled to the tank circuit through a metallic strip 23, the latter being located in the interior of the tank circuit 12. This coupling circuit includes an adjustable tuning inductance 24 (Fig. 1a) in the form of a coaxial line, the inner conductor of which is connected to the inner conductor of the coaxial line 22 and movable over a portion of the length of the coaxial line 22; also a variable condenser arrangement 25 located relatively close to the resonator 12 and at a voltage maximum point on the coaxial line 22. The movement of the coaxial line 24 over a portion of the length of the coaxial line 22 provides coarse tuning for the coupling circuit, while the effective length of the tuning inductance 24 determines the damping of the coupling circuit. The variable capacitor 25, on the other hand, serves as a micrometer adjustment to tune the coupling circuit.

A better understanding of the invention may be had by referring to Fig. 2 which is an equivalent electrical circuit of the main elements of Figs. 1 and 1a. Referring to Fig. 2, wherein the circuit elements which correspond to similar elements of Figs. 1 and 1a are given the same reference numerals with prime designations, it will be seen that the coupling circuit as a whole may be considered as a transformer. The tank circuit 12 may be said to be the primary of the transformer having uniformly distributed inductance and capacitance in parallel and is designated 12' in Fig. 2. The secondary of the transformer comprises the distributed inductance of the coaxial line 22 and coupling loop or strip 23, together with the distributed inductance of the coaxial line tuning element 24 in series, this distributed inductance taken as a whole being paralleled by the uniformly distributed capacitance provided by the coaxial line 22 and the concentrated capacitance provided by the variable condenser 25. The transmission line 21 which connects the secondary or coupling circuit to the useful load is permanently connected to the secondary at the junction point between the coaxial line 22 and the tuning element 24 and always appears in shunt with 24. The main inductance of the secondary comprising 23 and 22 is tunable by the movement of the tuning element 24 over a portion of the length of the coaxial line 22. The degree of coupling between the primary (electrical cavity resonator) 12 and the coupling circuit is determined by the position of the metallic spring-like slide 26 which contacts both the strip 23 and the inner surface of the adjacent sector of the resonator 12, while the effective length of the tuning element 24 determines the damping of the secondary circuit. Both of these adjustments provided by the slider 26 and the effective length of the tuning element 24 alter slightly the tuning of the secondary circuit and can be compensated for either by an adjustment of 25 or repositioning of 24 over the length of the coaxial line.

The metallic strip 23 of the coupling circuit is connected at one end to the inner conductor of the coaxial line 22 and at the other end directly connected to a metallic strip 27 to the electrical resonator. The dimensions of this strip 23 should preferably be such as to have the same electrical characteristics as the transmission line 22 which it terminates. At this time it should be noted that the surge impedance of the coaxial line 22 should preferably be equal to the surge impedance of transmission line 21 to which it connects at its other end. Transmission line 21 has a ratio of

diameters equal to the ratio of diameters of the coaxial line 22 and is matched to present a pure resistance to the coaxial line 22 at the junction point 58. In this way it will be obvious that the section of coaxial line 22 behind point 58 looking toward the useful load acts as an extension of the transmission line 21.

From what has gone before, it will be apparent that the degree of coupling between the primary and secondary of the transformer is determined by the area defined by the strip 23, the slider 26, the section of the sector of the resonator adjacent strip 23, and the extension of the inner conductor 22 in the interior of the resonator. In one embodiment actually tried out in practice, the strip 23 was one quarter of an inch wide and spaced one-quarter of an inch from the resonator 12, while the slider 26 was a phosphor bronze spring.

The details of the construction of the strip 23 and slider 26 are shown more clearly in Figs. 3 and 3a, from which it will be noted that the spring 26 is in the form of a U-shaped loop with tabs at the ends bent over the edges of 23.

The details of the micrometer variable condenser 25 are shown both in Fig. 1 and in Fig. 4, which are cross-sectional views at right angles to each other. This variable condenser comprises an adjustable plate 28 which is mounted at the end of a screw 29 which is threaded in a boss 30, the latter being fixed to a clamp 31. The other plate of the condenser 25 is indicated at 32 which is connected to the inner conductor of the coaxial line 22 by means of spring clip 33 and supported from clamp 31 by means of insulator 34. The clamp 31 comprises a split section of a cylinder having flanges at the edges of the adjoining halves, and held together by means of screws. The outer conductor of coaxial line 22 is provided with an aperture (here indicated at 35) for enabling the plates 28 and 32 to be inserted in the interior of the coaxial line. The elements of the condenser 25 are capable of being easily taken apart and put together, and the plates 28 and 32 are supported from the same element of the mounting 31, thus providing a rigid construction.

The tuning element 24 of Fig. 1a, another cross-section of which is shown in Fig. 5, comprises a coaxial line having an inner conductor 36 and an outer conductor 37, the latter being mounted on a split section of a cylindrical mounting 38 which surrounds the outer conductor of the coaxial line 22. The inner conductor 36 of the tuning inductance 24 is provided at one end with a spring clip 39 for contacting the inner conductor of the coaxial line 22, and at its other end is supported rigidly by the outer conductor 37 through the intermediary of the flange 40 to which it is fastened. Flange 40 is clamped between the two halves 37' and 37'' of the outer conductor 37, by virtue of overlapping cylindrical section 41, as shown. The effective length of the tuning inductance 24 is adjusted by means of slider 42 (contacting the outer surface of 36 and the inner surface of 37) which is movable over the length of 24 by means of rods 43, in turn linked to disc 44 which is threaded and driven by shaft 45 attached at one end to knob 46. Shaft 45, although free to rotate, is rigidly maintained in its desired position by means of end plate 47. The coaxial line 22 is provided with a longitudinal slot 48 extending over a desired portion of this length for enabling the tuning inductance 24 to be moved over this portion while maintaining proper contact with the conductors of the coupling circuit.

In the operation of the invention, coarse tun-

ing of the secondary is first effected by moving the position of the tuning element 24 over line 22 such that the secondary circuit is tuned to the mid-frequency of the band pass. The variable condenser 25, as mentioned before, serves as a micrometer adjustment to tune the secondary. The area of the loop defined by strip 23, slider 26 and the extension of the inner conductor of the coaxial line 22 into the interior of the resonator 12 should be adjusted to first obtain the desired band pass, and then for uniform response in the band pass the effective length of the tuning element 24 is adjusted. These last two adjustments will alter the tuning of the secondary and can be compensated for by a small change in the location of the tuning element 24 or an adjustment of condenser 25. The exact position of the condenser 25 on the coaxial line 22 will be determined by the position of the tuning element 24. It will thus be seen that the condenser 25 need not always be located at a voltage maximum point on the coaxial line 22, although such a location is preferred because the condenser 25 is most effective in such a position.

The sum of the lengths of the active part of 23, the part of 22 to the left of point 58, and the active part of 24 will be less than one-half the length of the operating wave, the amount less than one-half wavelength depending upon the value of the condenser 25. If the capacity of the condenser 25 were zero and the separate parts had the same characteristic impedance, then the sum of the parts would be one-half wavelength. In one embodiment tried out in practice at an operating frequency of 460 megacycles, the length of the active part of 23 was $2\frac{3}{4}$ "', the length of the inner conductor of coaxial line 22 from the point where it joins 23 to point 58 was $7\frac{1}{4}$ "', and the length of the active part of inductance element 24 was 1". The diameter of the inner conductor of line 22 was $\frac{1}{8}$ ". The inside diameter of the outer conductor of line 22 and of 24 was .78 inch. The diameter of the inner conductor of inductance 24 was $\frac{1}{4}$ ".

An important advantage of the present invention lies in the fact that the feed line 21 to the useful load is permanently fixed to the coupling circuit and need not be moved.

If desired, the condenser 25 can be eliminated and the adjustment of the coupling circuit effected solely by the slider 42 of the tuning element 24, and the adjustment of the tuning element 24 over the length of the coaxial line 22.

What is claimed is:

1. An energy transfer circuit comprising a coaxial line having a tunable inductance located between the ends of said coaxial line and shunted across the conductors thereof, said coaxial line having an opening in its outer conductor for a portion of its length, said inductance comprising a section of coaxial line whose inner conductor is electrically linked by means of a slidable connection to the inner conductor of said first coaxial line through said opening, and whose outer conductor is electrically connected by a slidable connection to the outer conductor of said first coaxial line, whereby said section is movable in position over a portion of the length of said first coaxial line, said coaxial line inductance having means for adjusting the effective length thereof.

2. An energy transfer circuit comprising a coaxial line having a variable condenser shunted across its conductors at substantially a voltage maximum point for the operating frequency,

and a tunable inductance located between the ends of said coaxial line and shunted across the conductors thereof, said inductance comprising a section of coaxial line having means for adjusting the effective length thereof, said section being movable in position over a portion of the length of said first coaxial line.

3. A band pass energy transfer circuit comprising a coaxial line coupled at one end to a source of high frequency energy and at its other end to a high frequency load, and having a tunable inductance of uniformly distributed inductance and capacitance located between the ends of said coaxial line and shunted across the conductors thereof, said coaxial line having an opening in its outer conductor for a portion of its length, said tunable inductance having one conductor electrically linked by means of a slidable connection to the inner conductor of said coaxial line through said opening, and another conductor electrically connected by a slidable connection to the outer conductor of said coaxial line, whereby said inductance is movable in position over a portion of the length of said coaxial line and is connected solely at one end to the conductors of said line, and means for adjusting the effective length of said inductance.

4. An energy transfer circuit comprising a coaxial line coupled at one end to a source of high frequency energy and at its other end to a high frequency load, a variable condenser shunted across the conductors of said line intermediate its ends, and a tunable inductance of uniformly distributed inductance and capacitance located between the ends of said coaxial line and shunted across the conductors thereof, said inductance being movable in position over a portion of the length of said coaxial line and being connected solely at one end to the conductors of said line, and means for adjusting the effective length of said inductance.

5. An energy transfer circuit comprising a coaxial line coupled at one end to a source of high frequency energy and at its other end to a high frequency load, the outer conductor of said line having a slot therein over a portion of the length thereof, a tunable inductance in the form of a section of coaxial line having its inner conductor slidably connected at one end to the inner conductor of said first line through said slot and having its outer conductor connected at said same end to the outer conductor of said first line by means of a clamp, said clamp surrounding said slot and being movable over the length of said slot for varying the position of said inductance, and a slider connecting together the conductors of said inductance and movable over a portion of the length of said inductance.

6. In combination, an electrical resonator in the form of an enclosed metallic chamber, a utilization circuit, and an energy transfer circuit coupling said resonator to said utilization circuit, said transfer circuit comprising a coaxial line having one end coupled to said resonator and the other end coupled to said utilization circuit, the inner conductor of said coaxial line being coupled to said resonator by means of a conductor extending through an aperture in said resonator and forming an inductive loop in the interior of said resonator, means in circuit with said loop and contacting said resonator in the interior thereof for adjusting the degree of coupling between said resonator and said transfer circuit, and means for tuning said transfer circuit comprising tunable inductance in the form

of a section of coaxial line shunted across the conductors of said first coaxial line and located intermediate the ends of said first line, said tunable inductance having means for adjusting the effective length thereof.

7. In combination, an electrical resonator in the form of an enclosed metallic chamber, a utilization circuit, and an energy transfer circuit coupling said resonator to said utilization circuit, said transfer circuit comprising a coaxial line having one end coupled to said resonator and the other end coupled to said utilization circuit, the inner conductor of said coaxial line being coupled to said resonator by means of a conductor extending through an aperture in said resonator and forming an inductive loop in the interior of said resonator, means in circuit with said loop and contacting said resonator in the interior thereof for adjusting the degree of coupling between said resonator and said transfer circuit, and means for tuning said transfer circuit comprising tunable inductance in the form of a section of coaxial line shunted across the conductors of said first coaxial line and located intermediate the ends of said first line, said tunable inductance having means for adjusting the effective length thereof and being movable as a whole over a portion of the length of said first coaxial line.

8. A combination as defined in claim 7, characterized in this that said tunable inductance is connected solely at one end to said first coaxial line, there being provided means located at substantially a voltage maximum point on said first line for varying the capacity between the conductors of said first line.

9. In combination, an electron discharge device having a cavity resonator associated therewith, a coupling circuit coupled at one end to said cavity resonator, and at its other end to a load, said coupling circuit comprising a coaxial line having an extension of its inner conductor protruding into the interior of said resonator through an aperture, said extension being inductively coupled to said resonator in said interior, means in the interior of said resonator for varying the degree of coupling between it and said inner extension, said coaxial line having an opening in the outer conductor thereof which is located externally of said resonator, and a section of another coaxial line having its inner conductor coupled at one end to the inner conductor of said first coaxial line through said opening and having its outer conductor at said same end coupled to the outer conductor of said first coaxial line, means for adjusting the effective length of said section, and means located between said cavity resonator and said section for varying the capacity between the conductors of said first coaxial line.

10. In combination, an electron discharge device having a cavity resonator associated therewith, a coupling circuit coupled at one end to said cavity resonator and at its other end to a load, said coupling circuit comprising a coaxial line having an extension of its inner conductor protruding into the interior of said resonator through an aperture, said extension being inductively coupled to said resonator in said interior, means in the interior of said resonator for varying the degree of coupling between it and said inner extension, said coaxial line having an opening in the outer conductor thereof which is located externally of said resonator, and a section of another coaxial line having its

inner conductor coupled at one end to the inner conductor of said first coaxial line through said opening and having its outer conductor at said same end coupled to the outer conductor of said first coaxial line, means for adjusting the effective length of said section, said load having its surge impedance matched to the impedance of said coupling circuit.

11. An energy transfer circuit comprising a coaxial line having a variable condenser shunted across its conductors, and a tunable inductance located between the ends of said coaxial line and shunted across the conductors thereof, said inductance comprising a section of coaxial line having means for adjusting the effective length thereof, said section being connected to said line by slidable connections, whereby it is movable in position over a portion of the length of said first coaxial line.

12. In combination, an electrical resonator, a utilization circuit, and an energy transfer circuit coupling said resonator to said utilization circuit, said transfer circuit comprising a coaxial line having one end coupled to said resonator and the other end coupled to said utilization circuit, the inner conductor of said coaxial line being coupled to said resonator by means of a conductor extending through an aperture in said resonator and forming an inductive loop in the interior of said resonator, a metallic strip in circuit with said loop and contacting said resonator in the interior thereof for adjusting the degree of coupling between said resonator and said transfer circuit, and a tunable inductance in the form of a section of coaxial line shunted across the conductors of said first coaxial line and located intermediate the ends of said first line, said tunable inductance having a short-circuiting bridge for adjusting the effective length thereof and being movable as a whole over a portion of the length of said first coaxial line.

13. In combination, an electron discharge device having a cavity resonator associated therewith, an output circuit coupled to said cavity resonator, said output circuit comprising a coaxial line having its inner conductor entering the interior of said resonator through an aperture and insulatingly spaced from said resonator, said inner conductor being inductively coupled to said resonator in said interior, means in the interior of said resonator for varying the coupling between it and said inner conductor, said coaxial line having an opening in the outer conductor externally of said resonator, and a section of another coaxial line having its inner conductor coupled at one end to the inner conductor of said output circuit through said opening and its outer conductor at said same end coupled to the outer conductor of said output circuit, the other end of said section being short circuited, and slidable means within said section for adjusting the effective length thereof.

14. A system in accordance with claim 13, characterized in this that said opening in the outer conductor of said output circuit is a slot, and said section is movable over said output circuit for the length of said slot.

15. In combination, an electron discharge device having a tuned circuit in the form of a cavity resonator associated therewith, an output circuit coupled to said cavity resonator, said output circuit comprising a coaxial line having its inner conductor entering the interior of said resonator through an aperture and insulatingly spaced from said resonator, said inner conductor

being inductively coupled to said resonator in said interior by means of a loop, adjustable means in contact with said loop for varying the amount of coupling between said resonator and said inner conductor, said coaxial line having an opening in the outer conductor externally of said resonator, and a section of another coaxial line having its inner conductor coupled at one end to the inner conductor of said output circuit through said opening and its outer conductor at said same end coupled to the outer conductor of said output circuit, and means for adjusting the effective length of one of said coaxial lines.

16. In combination, an electron discharge device having a tuned circuit in the form of a cavity resonator associated therewith, an output circuit coupled to said cavity resonator, said output circuit comprising a coaxial line having its inner conductor inductively coupled to the resonator in its interior through an aperture therein, a variable capacitor across said line at the end nearest said resonator, means for varying the coupling between said resonator and said inner conductor, said coaxial line having an opening in the outer conductor external of said resonator, and a section of another coaxial line having its inner conductor coupled at one end to the inner conductor of said output circuit through said opening and its outer conductor at said same end coupled to the outer conductor of said output circuit, and means for adjusting the effective length of one of said coaxial lines.

17. In combination, an electron discharge device having a cavity resonator associated therewith, an output circuit coupled to said cavity resonator, said output circuit comprising a coaxial line having its inner conductor entering the interior of said resonator through an aperture and insulatingly spaced from said resonator, said inner conductor being inductively coupled to said resonator in said interior by means of a loop, adjustable means directly engaging said loop for varying the amount of coupling between said resonator and said inner conductor, said coaxial line having an opening in the outer conductor externally of said resonator, and a section of another coaxial line having its inner conductor cou-

pled at one end to the inner conductor of said output circuit through said opening and its outer conductor at said same end coupled to the outer conductor of said output circuit, and tuning means in the form of a slider within one of said coaxial lines for adjusting the effective length of said one coaxial line.

18. In combination, an electron discharge device having a cavity resonator associated therewith, an output circuit coupled to said cavity resonator, said output circuit comprising a coaxial line having its inner conductor inductively coupled to the resonator in its interior through an aperture therein, a variable capacitor across said line at the end nearest said resonator, means for varying the coupling between said resonator and said inner conductor, said coaxial line having an opening in the outer conductor external of said resonator, and a section of another coaxial line having its inner conductor coupled at one end to the inner conductor of said output circuit through said opening and its outer conductor at said same end coupled to the outer conductor of said output circuit, and tuning means in the form of a slider within one of said coaxial lines for adjusting the effective length of said one coaxial line.

19. In combination, an electron discharge device having a cavity resonator associated therewith, an output circuit coupled to said cavity resonator, said output circuit comprising a coaxial line having its inner conductor inductively coupled to the resonator in its interior by means of a loop, adjustable means for varying the amount of coupling between said resonator and said inner conductor, said coaxial line having an opening in the outer conductor external of said resonator, and a section of another coaxial line having its inner conductor coupled at one end to the inner conductor of said output circuit through said opening and its outer conductor at said same end coupled to the outer conductor of said output circuit, tuning means in the form of a slider within one of said coaxial lines for adjusting the effective length of said one coaxial line, and a load connected to the other coaxial line.

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