May 29, 1951 D. H. PREIST 2,554,501

RADIO-FREQUENCY GENERATOR

Filed Jan. 17, 1949 2 Sheets-Sheet 1

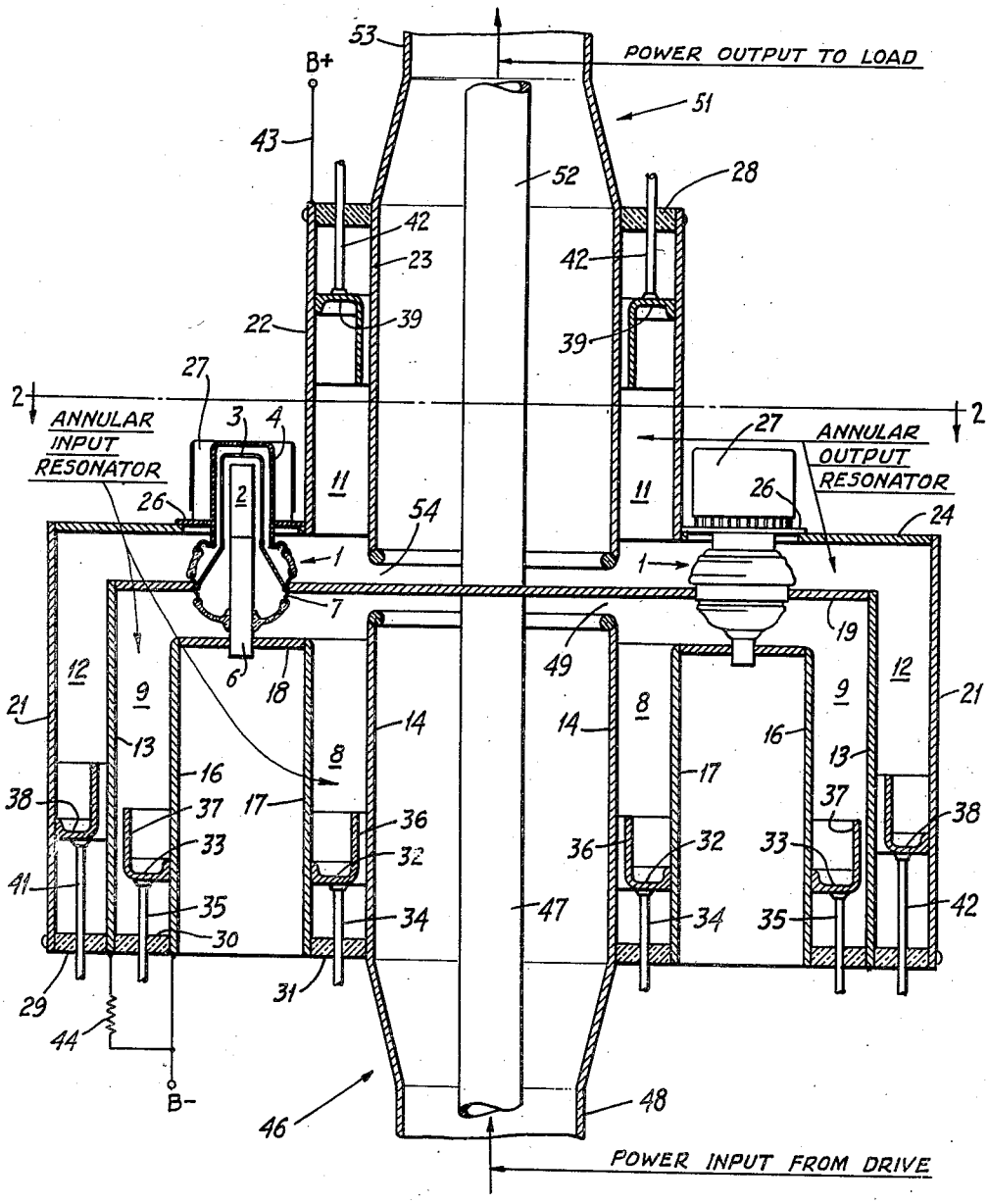


Fig. 1

INVENTOR.
Donald H. Preist
BY Harold E. Long

ATTORNEY

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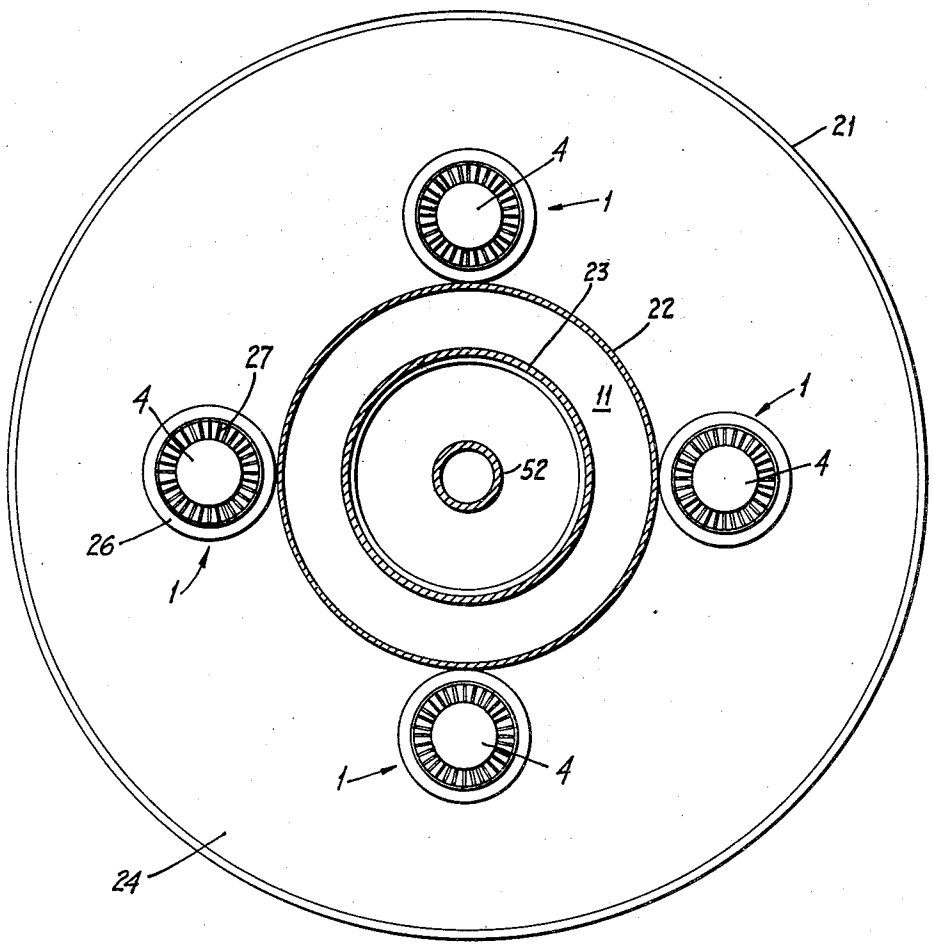


Fig. 2

INVENTOR.
Donald H. Preist
BY Harold E Day

ATTORNEY

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RADIO-FREQUENCY GENERATOR

Donald H. Preist, Tiburon, Calif., assignor to Eitel-McCullough, Inc., San Bruno, Calif., a corporation of California

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9 Claims. (Cl. 179—171)

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My invention relates to generators of radio-frequency power, and more particularly to such a generator capable of delivering large orders of power in the higher frequency ranges, say above 100 mcs./sec., using conventional type negative grid tubes.

In my co-pending application, Serial No. 42,-171, filed August 3, 1948, I have disclosed a new type of R. F. generator embodying an annular cavity resonator operating in conjunction with a plurality of tube units, whereby the power outputs of the individual tube units are combined without appreciable loss.

The object of my present invention is to provide an improved resonator construction for such a multiple unit tube generator.

The invention possesses other objects and features of advantage, some of which, with the foregoing, will be set forth in the following description of my invention. It is to be understood that I do not limit myself to this disclosure of species of my invention as I may adopt variant embodiments thereof within the scope of the claims.

Referring to the drawings:

Figure 1 is a vertical sectional view of a power amplifier embodying the improvements of my invention; and

Figure 2 is a transverse sectional view taken in a plane indicated by the line 2—2 of Figure 1.

In terms of broad inclusion, the radio-frequency generator of my invention comprises a plurality of electron tube units disposed in a circle about an axis, and a pair of annular cavity resonators coaxial with the circle and having conductors connected to electrodes of the tube units, each resonator comprising two communicating annular cavity sections. As embodied in an amplifier, one of these cavity resonators functions as the input circuit, and the other as the output circuit, means being provided for feeding R. F. power into and out of the resonators, and means being provided in the resonators for tuning them to the resonant frequency. In the resonator construction of my present invention, one cavity section of the output resonator and both cavity sections of the input resonator extend downwardly from a plane defined by the circle of tube units, the other cavity section of the output resonator extending upwardly from such plane. In other words, one of the cavity sections of the output resonator is folded down to lie alongside the cavity sections of the input resonator. By this arrangement, the amplifier can be designed so that the tube units are exposed externally rather than being confined by

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the cavity structure. This construction not only makes it more convenient to service the equipment and replace the tubes, but also makes it possible to use a symmetrical transmission line and coupling system for feeding power into and out of the generator.

In greater detail, and referring to the drawings, my improved R. F. generator constructed as an amplifier comprises a plurality of electron tube units 1 disposed in a circle about a common axis, which tube units are of like structure and have like characteristics. While four tube units are shown, it is understood that any desired number may be employed, depending upon the power output required. Any conventional type of negative grid electron tube may be used for the units 1, the triode type of tube illustrated having a cathode 2, grid 3 and anode 4, the anode being external and all the electrodes being preferably cylindrical and coaxial.

The tube units employed also preferably have coaxial terminals for the electrodes, such as the cathode terminal 6 opposite the anode and the grid terminal ring 7 interposed in the glass envelope wall between the cathode terminal and anode. The heating structure for the cathode is not shown but may comprise any suitable means such as an inner filament for heating the cathode cylinder 2 by electron bombardment, in which case the filament leads preferably extend out through the tubular cathode terminal 6.

The amplifier has a pair of annular cavity resonators common to the tube units 1, functioning as the input and output resonant circuits for such units. Each resonator has two communicating annular cavity sections arranged coaxially with the circle of tube units, thus the input resonator has the two annular cavity sections 8 and 9 communicating through spaces between the lower portions of the tube units, and the output resonator has the two annular cavity sections 11 and 12 communicating through spaces between the upper portions of the tube units. This symmetrical arrangement of the cavity resonators with respect to the tube units is an important feature in my R. F. generator.

The two cavity sections 8 and 9 of the input resonator extend downwardly from a plane defined by the circle of tube units, say a plane passing through the mid-portions of the units 1. Cavity section 12 of the output resonator also extends downwardly from such plane and surrounds the input resonator, while the other cavity section 11 of the output resonator extends upwardly from the plane of the tube circle.

In my earlier application, hereinbefore mentioned, both cavity sections of the output resonator extend upwardly, which is entirely satisfactory electrically but makes it hard to get at the tubes. By folding down the outer cavity section of the output resonator, as shown in Figure 1, it will be seen that the tube units are exposed on a deck of the amplifier, which is a more convenient and desirable arrangement from the mechanical standpoint.

The several cavity sections of the resonators are defined by metallic boundary walls or conductors which make up the physical structure of the amplifier. As illustrated, the input resonator comprises four concentric wall conductors 13, 14, 16 and 17, the inner wall conductors 16 and 17 being shorter than the conductors 13 and 14. This forms the annular cavity section 9 between the walls 13 and 16, and the second annular cavity section 8 between the walls 14 and 17. The shorter walls are connected across the top by a metal ring 18, these parts comprising an inner conductor of the resonator. This inner conductor is connected to the cathode 2 of each of the tube units, preferably by having cathode terminals 6 seated in apertures or sockets in the ring 18. Suitable leads for the cathode heater means may conveniently extend out through the hollow space formed between the inner walls 16 and 17.

A transverse conductor member or metal disk 19 extends across the top of the input resonator in the plane of the grid terminal rings 7 and is connected to the cylinder 13. This transverse conductor comprises the top wall of the input cavity 8—9 and also forms a common dividing wall between the input and output resonators. It is connected to the grid 3 of each of the tube units, preferably by having the grid terminal rings 7 seated in apertures or sockets spaced about the disk 19. Cavity sections 8 and 9 of the input resonator are thus connected about their circumference by the communicating space formed between the transverse wall members 18 and 19.

The annular cavity sections of the output resonator are defined by a cylindrical wall 21 surrounding the wall 13 to form the cavity section 12, and by a pair of upwardly extending cylindrical walls 22 and 23 forming the cavity section 11. Wall conductors 21 and 22 are joined by a transverse wall conductor 24 which is connected to the anode 4 of each of the tube units. Cavity sections 11 and 12 of the output resonator are thus also connected about their circumference by the communicating space formed between the transverse wall members 19 and 24.

By this arrangement it will be seen that the cavity resonators are coaxial with the circle of tube units, and are disposed in such a manner that the tube units are located between the annular cavity sections of the resonators, with the cathodes connected to a conductor of the input resonator, the anodes connected to a conductor of the output resonator and the grids connected to a common transverse conductor between the resonators. This symmetrical arrangement of the cavity resonators with respect to the tube units is an important feature as pointed out in my earlier application hereinbefore mentioned.

It will also be noted that the folding down of the cavity section 12 of the output resonator in my present construction places the tube units 1 on an open deck, which is a desirable feature from the standpoint of tube replacement and servicing the equipment. Connection of the anodes 4 to the transverse deck plate or conductor 24 is preferably made by terminal rings 26 on the anodes of a size to seat down on the deck 24. Coolers 27 on the anodes are placed above the anode terminal rings 26. These coolers may be of the finned type for forced air cooling as illustrated, or may be suitable jackets for water cooling the anodes. In either case the coolers are exposed for convenient connection of air or water ducts. The apertures in the transverse conductors 24, 19 and 18 are of a size to permit withdrawal and replacement of the tube units.

The several cylindrical conductors of the resonators are held mechanically in position by rings 28, 29, 30 and 31 of suitable insulating material located between the conductors at the top and bottom of the generator. Any suitable metal such as brass may be used for the various cylindrical and transverse conductors described.

Adjustable means are provided for tuning the input and output resonators to control the resonant frequency. For this purpose a pair of movable annular metal plungers or rings 32 and 33 are provided in the input resonator, forming end walls in the cavity sections 8 and 9 respectively. These plungers are slideably mounted on the inner wall conductors 17 and 16, and axial adjustment is achieved by means of plunger rods 34 and 35 of insulating material projecting out through the supports 31 and 30. These rods may be connected externally to insure that the end plates 32 and 33 are adjusted in unison. Plungers 32 and 33 are preferably spaced from the wall conductors 14 and 13 and have cylindrical flanges 36 and 37 so that the devices also function at chokes to confine the R. F. and isolate D. C. voltages. For this purpose the flanges 36 and 37 are made effectively a quarter-wave long at the operating frequency, telescoping sleeves (not shown) being preferably provided on the flanges to adjust their length.

In a like manner plungers 38 and 39 are provided in the cavity sections 12 and 11 of the output resonator, which plungers are slideably mounted on the wall conductors 21 and 22 respectively and have flanges spaced from the walls 13 and 23. These plungers thus serve as means for tuning the output resonator and as chokes for confining the R. F. and isolating the D. C. voltage, tuning adjustment being effected by the rods 41 and 42.

The D. C. voltages may be applied to the tube electrodes in any suitable manner. In the amplifier illustrated, which is essentially a grid-separation type of circuit, the positive D. C. anode potential is applied by connection to the outer conducting wall as indicated at 43, and the grid bias voltage is applied via the conductors 13—19 by a grid bias resistor as indicated at 44. Suitable leads (not shown) for the cathode heaters for the several tube units are conveniently brought out through the hollow space between the conductors 16 and 17.

Instead of using the tuning plungers as chokes, the D. C. voltages may be isolated by suitable bypass condensers at the anode and grid terminals of the tube units, as will be appreciated by those skilled in the art, in which case the tuning plungers 32, 33, 38 and 39 may be simple shorting bars slideable along the conductor walls. This also has the advantage of removing the D. C. voltage from the wall conductors of the generator, the anode voltage connections being made directly to

the anodes of the tubes. Of course the electrodes are still connected for R. F. to the conductors of the resonators, it being understood that such connections may be established through suitable bypass condensers as well as by direct connection.

Radio-frequency input driving power to the amplifier is preferably transferred to the input resonator from a suitable source of drive by means of a hollow transmission line 46, preferably of the coaxial type having an inner conductor 47 and an outer conductor 48. This transmission line extends axially of the generator with the inner conductor 47 terminating at the transverse wall conductor 19 and with the outer conductor conveniently formed as a continuation of the innermost wall 14 of the input resonator. Energy coupling means between the transmission line and input resonator preferably comprises a circular slot 49 formed by spacing the end of conductor 14 from the transverse conductor 19. The circular arrangement of this coupling slot is desirable because it provides uniform coupling of energy from the transmission line to the annular input resonator.

Radio-frequency energy is preferably transferred from the output resonator to the load by a similar transmission line 51 comprising an inner conductor 52 terminating at the transverse conductor 19 and an outer conductor 53 formed as a continuation of the innermost wall conductor 23 of the output resonator. A circular slot 54 serves to couple energy from the output resonator to the transmission line.

Other suitable means may be employed for transferring and coupling power into and out of the resonators, but the coaxial and symmetrical arrangement shown is highly efficient and is preferred.

It is understood that the generator may be operated as a self-excited oscillator by eliminating the input transmission line 46 and by providing suitable feedback coupling means for establishing feedback of energy from the output resonator to the input resonator to sustain oscillation.

In my improved R. F. generator, operating either as an amplifier or as an oscillator, the overall diameter of the generator may be increased indefinitely to accommodate an indefinite number of tube units, depending upon the amount of power required. Furthermore, the multiple unit tube generator will operate well in the higher frequency ranges, say above 500 mcs./sec., without loss of efficiency compared to that obtainable from a single tube unit. The total power output from n tube units, as measured at the load, is substantially n times that obtainable from a single tube unit in an efficient single unit tube generator.

While I have described my generator in connection with triode units, it is understood that tube units having additional electrodes such as tetrodes may be employed, in which case additional annular, coaxial and symmetrical circuit members are employed.

I claim:

1. A radio-frequency generator comprising a plurality of electron tube units disposed in a circle about an axis and each having electrodes, and a cavity resonator common to the tube units and having two communicating annular cavity sections, the resonator being coaxial with said circle and having a conductor connected to an electrode of each of said tube units, one of the cavity sections of the resonator extending in one direction relative to the plane of said circle and the other cavity section extending in the opposite direction, and a second cavity resonator common to the tube units and having two communicating annular cavity sections, the second resonator being coaxial with said circle and having a conductor connected to another electrode of each of said tube units, both of the cavity sections of the second resonator extending in the same direction relative to the plane of said circle.

2. A radio-frequency generator comprising a plurality of electron tube units disposed in a circle about an axis and each having electrodes including an anode and cathode, an output cavity resonator common to the tube units and having two communicating annular cavity sections, the output resonator being coaxial with said circle and having a conductor connected to the anode of each of said tube units, one of the cavity sections of the output resonator extending in one direction relative to the plane of said circle and the other cavity section extending in the opposite direction, and an input cavity resonator common to the tube units and having two communicating annular cavity sections, the input resonator being coaxial with said circle and having a conductor connected to the cathode of each of said tube units, both of the cavity sections of the input resonator extending in the same direction relative to the plane of said circle.

3. A radio-frequency generator comprising a plurality of electron tube units disposed in a circle about an axis and each having electrodes including an anode and cathode and grid, an output cavity resonator common to the tube units and having two communicating annular cavity sections, the output resonator being coaxial with said circle and having a conductor connected to the anode of each of said tube units, one of the cavity sections of the output resonator extending in one direction relative to the plane of said circle and the other cavity section extending in the opposite direction, an input cavity resonator common to the tube units and having two communicating annular cavity sections, the input resonator being coaxial with said circle and having a conductor connected to the cathode of each of said tube units, both of the cavity sections of the input resonator extending in the same direction relative to the plane of said circle, and a conductive member common to said resonators extending transversely of said axis and connected to the grid of each of said tube units.

4. A radio-frequency generator comprising a plurality of electron tube units disposed in a circle about an axis and each having electrodes including an anode and cathode, an output cavity resonator common to the tube units and having two communicating annular cavity sections, the output resonator being coaxial with said circle and having a conductor connected to the anode of each of said tube units, one of the cavity sections of the output resonator extending in one direction relative to the plane of said circle and the other cavity section extending in the opposite direction, an input cavity resonator common to the tube units and having two communicating annular cavity sections, the input resonator being coaxial with said circle and having a conductor connected to the cathode of each of said tube units, both of the cavity sections of the input resonator extending in the same direction relative to the plane of said circle, an input transmission line extending axially of the input resonator, an output transmission line ex-

tending axially of the output resonator, and energy coupling means between each line and its resonator.

5. A radio-frequency generator comprising a plurality of electron tube units disposed in a circle about an axis and each having electrodes including an anode and cathode, an output cavity resonator common to the tube units and having two communicating annular cavity sectios, the output resonator being coaxial with said circle and having a conductor connected to the anode of each of said tube units, one of the cavity sections of the output resonator extending in one direction relative to the plane of said circle and the other cavity section extending in the opposite direction, an input cavity resonator common to the tube units and having two communicating annular cavity sections, the input resonator being coaxial with said circle and having a conductor connected to the cathode of each of said tube units, both of the cavity sections of the input resonator extending in the same direction relative to the plane of said circle, an input transmission line extending axially of the input resonator, an output transmission line extending axially of the output resonator, and energy coupling means between each line and its resonator, said coupling means comprising circular slots communicating between the lines and the respective resonators.

6. A radio-frequency generator comprising a plurality of electron tube units disposed in a circle about an axis and each having electrodes including an anode and cathode, an output cavity resonator common to the tube units and having two communicating annular cavity sections, the output resonator being coaxial with said circle and having a conductor connected to the anode of each of said tube units, one of the cavity sections of the output resonator extending in one direction relative to the plane of said circle and the other cavity section extending in the opposite direction, an input cavity resonator common to the tube units and having two communicating annular cavity sections, the input resonator being coaxial with said circle and having a conductor connected to the cathode of each of said tube units, both of the cavity sections of the input resonator extending in the same direction relative to the plane of said circle, and adjustable tuning means in the cavity sections of the input and output resonators for controlling the resonant frequency of said resonators.

7. A radio-frequency generator comprising a plurality of electron tube units disposed in a circle about a common axis, each tube unit having a plurality of electrodes, an input resonator comprising a pair of communicating concentric annular cavity sections extending axially and in the same direction from said circle, said input resonator having a conductor electrically connected to an electrode of each of said tube units, an output resonator comprising a second pair of communicating concentric annular cavity sections extending axially from said circle, one of the cavity sections of the second pair extending in the direction of and surrounding the cavity sections of said input resonator, and the other of the cavity sections of the second pair extending in the opposite direction and lying within the circle of tube units, whereby said tube units are readily accessible for testing and replacement, said output resonator having a conductor electrically connected to another electrode of each of said tube units.

8. A radio-frequency generator comprising a plurality of electron tube units disposed in a circle about a common axis, each tube unit having anode, cathode, and grid electrodes, an input resonator comprising a pair of communicating concentric annular cavity sections extending axially and in the same direction from said circle, said input resonator having a conductor electrically connected to the cathode of each of said tube units, an output resonator comprising a pair of communicating concentric annular cavity sections extending axially from said circle, one of said last named cavity sections extending in the direction of and surrounding the cavity sections of said input resonator, and the other of said last named cavity sections extending in the opposite direction and lying within the circle of tube units, whereby said tube units are readily accessible for testing and replacement, said output resonator having a conductor electrically connected to the anode of each of said tube units, and a conductor common to said resonators and electrically connected to a grid of each of said tube units.

9. A radio-frequency generator comprising a plurality of electron tube units disposed in a circle about a common axis, each tube unit having a plurality of electrodes, an input resonator comprising a pair of communicating concentric annular cavity sections extending axially and in the same direction from said circle, said input resonator having a conductor electrically connected to an electrode of each of said tube units, an output resonator comprising a pair of communicating concentric annular cavity sections extending axially from said circle, one of said last named cavity sections extending in the direction of and surrounding the cavity sections of said input resonator, and the other of said last named cavity sections extending in the opposite direction and lying within the circle of tube units, whereby said tube units are readily accessible for testing and replacement, said output resonator having a conductor electrically connected to another electrode of each of said tube units, said last named conductor comprising an annular deck plate transverse to said axis, said deck plate being apertured to receive said tube units.

DONALD H. PREIST.

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